CHEMISTRY

ARTICLES YOU CAN UNDERSTAND

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25¢

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Freedom From Fear?

▶ TODAY the world is sick with fear. It is a many-dimensional fear. The deeper that one looks into the problems arising from the atom bomb the more facets of danger one discerns. A crisis is at hand with which we dare not temporize. The sincerest thinking of the most unselfish minds our country can produce is the only hope we have.

On the surface, we find the fear of the old Army men: that the other fellow will get an atom bomb before we can perfect our own defense.

But against the atomic bomb there is no defense.

Just below the suface lurks the Diplomat's fear: if we give away the atomic power secret we will lose our bargaining power.

But there is no atomic power secret.

Again, below that, lies the Isolationist's fear: how can we trust the other fellow?

But, if we can't trust him, we are already lost in the maddest armament race our nightmare imaginations can project.

On one side is the Industrialist's fear: will this new power source upset the economic structure of the country and my private apple cart?

This new power is a discovery at least as great as man's discovery of fire. Who can predict what will come of it?

On the other side is the Practical Man's fear: will we get our money back from this great investment?

Who wants to buy Plutonium for atomic bombs?

The thoughtless Flag Waver cries: all the world will look up to the United States now!

Do we want leadership based on such a threat?

Suspicion whispers: we must never tell anyone what we know!

To the scientist, that is the blackest fear of all. Not to be allowed to seek the truth wherever it leads him means death to science, which is dearer to the scientist than life itself. It means death to our great civilization, whose foundation is knowledge and whose goal is liberty.

Are we ready to pay that price?

CHEMISTRY

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▸ THE ARMY OF THE FUTURE *will consist of one general and an atom bomb, according to the view of the cartoonist in "El Universal," Mexico City.*

▸ THE SERIOUSNESS *of the responsibility scientists feel about turning this fantastic weapon loose on an irresponsible war-making world was stated by Dr. J. Robert Oppenheimer, Director of the Los Alamos, New Mex. laboratory:*

"By our works we are committed, committed to a world united, before this common peril, in law and in humanity."

AT HOME AND AT WORK ON

➤ HANFORD ENGINEER WORKS, HANFORD, WASHINGTON. *"Although the plant and site development at Hanford is very impressive, it is all under one company dealing with but one general operation so that it is in some respects less interesting than Clinton, which has a great multiplicity of activity. . . .*

THE NUCLEAR BOMB PROJECTS

▶ CLINTON ENGINEER WORKS, OAK RIDGE, TENN. . . . *To describe the Clinton site, with its great array of new plants, its new residential districts, new theaters, new school system, seas of mud, clouds of dust, and general turmoil is outside the scope of this report."—The Smyth Report.*

▶ CHARLES E. MUNROE, *explosives chemist, who discovered the principle of stand-off which has recently been applied to weapons. From a portrait in the Cosmos Club, Washington, D. C.*

Effect of Shaped Charge Discovered by U. S. Chemist

The Munroe Effect

by Dr. Frank Thone

Washington, D. C., although newest of the world's great capital cities, is already old enough to be a trifle casual about its historic shrines and landmarks of scientific progress. Some of its most notable spots are quite inconspicuously labeled; some are not labeled at all.

A visitor in Washington, invited by a scientific friend to drop in and see him at the Cosmos Club, might spend hours in the lounge of that noted rookery of research men without suspecting that this classically proportioned room is the ancestral hall of that most modern of weapons, the bazooka. Nor would he be likely to suspect that this war-baby had antecedents going back well over half a century.

Up near one end of the room is a fireplace, in front of which is a most peculiar-looking firescreen—a rather heavy and clumsy piece of furniture, you might say at first glance. It consists of a score or so of thick steel plates linked together, each about five or six inches square and as thick as a big man's hand; the whole collection is hung on a stout steel frame.

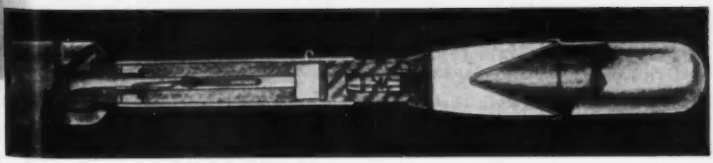
A little closer examination shows that each of the plates has a wide shallow dent or depression in its middle. At the bottom of each dent is a pattern of some kind, engraved into the metal. One is the outline of a maple leaf, another is of several of those red or gilt paper seals with which lawyers like to ornament their documents. Unless you had someone with you to explain the thing, it might seem merely odd and puzzling. One or two of the plates are cracked clear through.

Expert on "Bangs"

On the opposite wall, but near the other end of the room is a big oil portrait. It shows a benevolent-looking but keen-eyed old gentleman glancing up from a paper he has been reading. He is identified as the late Dr. Charles E. Munroe, member of the club from its earliest days in 1882 until his death in 1938, when he was almost 90 years old.

Dr. Munroe, your host will tell you,

This break-away diagram *of the "bazooka" rocket projectile shows the conical hollow in the explosive charge. The long empty space in front gives the "stand-off" necessary for maximum penetration effect.*



was a chemist who spent a long research career on the kind of chemistry most boys dream about when they first begin messing around with test-tubes and beakers. All his life he worked on things that go off with a loud bang. He was an explosives chemist. Almost all of his work was performed in government service: the Navy, the Bureau of Mines, the Forest Service, the National Research Council were among the beneficiaries of his more than 60 years of investigations of the nature and action of high explosives.

Worked With Guncotton

In 1888, when guncotton and other detonating nitrates were still more or less in the novelty class, Dr. Munroe was trying the effects of exploding charges of them on top of stout steel plates. A wad of guncotton thus set off, he found, might make a shallow dent, but that was about all. But if he placed some flat object, no matter how thin and fragile, between the charge and the steel, the dent would be deeper, and the pattern of the leaf, or bit of paper, or what-have-you, would be bitten sharply into the metal.

That was the genesis of the firescreen in the Cosmos Club lounge. He made up a number of such explosion-engraved plates, which were linked up to form that odd-looking bit of furniture, which has stood in the same place for many years.

This unpredicted and seemingly paradoxical behavior of high explosives, of blasting steel (or rock) more deeply if the side facing the solid surface were hollowed out and backed off a bit, became known as the Munroe effect. It was used in peacetime for certain special types of blasting, but military applications were not suggested until World War II was already under way.

Hollow Aids Penetration

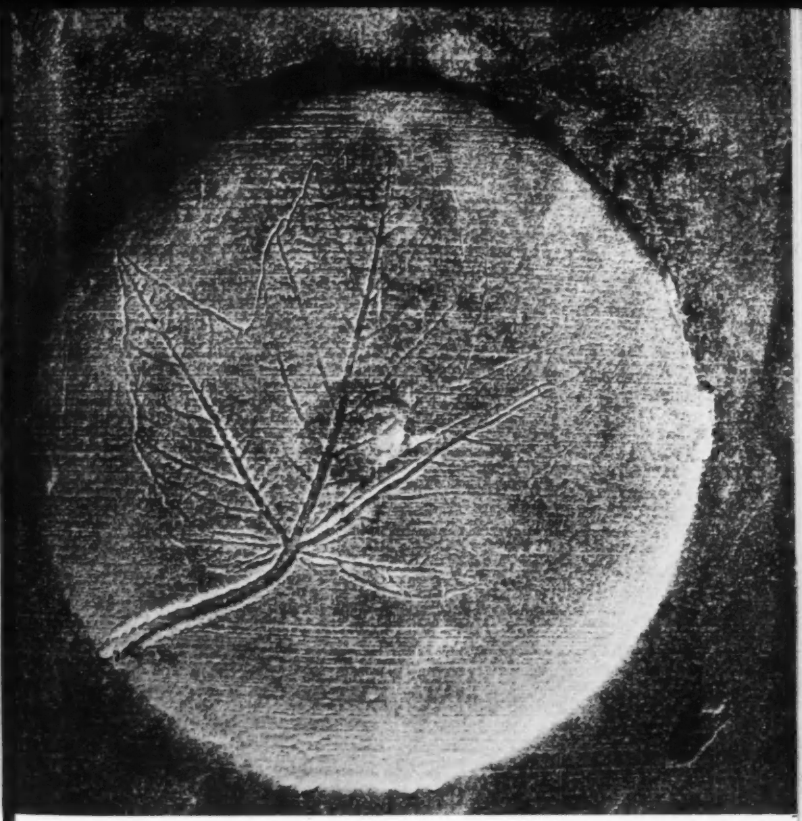
Further research presently showed that a maximum effect was obtained when the hollow in the face of the explosive charge was made really deep —an inverted cone with an 80-degree angle was found particularly effective. Furthermore, greatest results were obtained when the hollow charge was not exploded directly in contact with the steel, but held away from it a few inches. This distance, which varies according to type of explosive, shape and depth of the hollow cone, and kind of material to be attacked, is technically called the "stand-off."

On the mantelpiece above the Munroe firescreen there has recently been placed an exhibit that brings out these points most dramatically. It consists of a stack of ten pieces of five-eighths-inch armor plate which was subjected to a blast from one of these hollow-cone charges, then sawed in two to show what happened. The charge consisted of one-half pound of high explosive, with an 80-degree hollow cone in its face. It was set up on short legs, to give it a six-inch stand-off.

Blasted Through the Plates

The sawed-through section shows a rough walled hole blasted right through the pile of plates, which were also bent downward and fused together in the area around the hole. Greatest diameter of the opening is about an inch, near the top; smallest diameter, a little above the bottom, is a trifle less than one-half inch.

No solid object made that hole through the six and one-quarter inches



THE DELICATE STRUCTURE *of the maple leaf was blown into the hard steel plate by the explosive set off above it.*

of armor. It was stabbed through by a jet of naked, hard, unimaginably violent flame—a literal fiery sword. After lancing through the laminated steel, the flame-jet bored on into the ground for another nine inches before it was quenched.

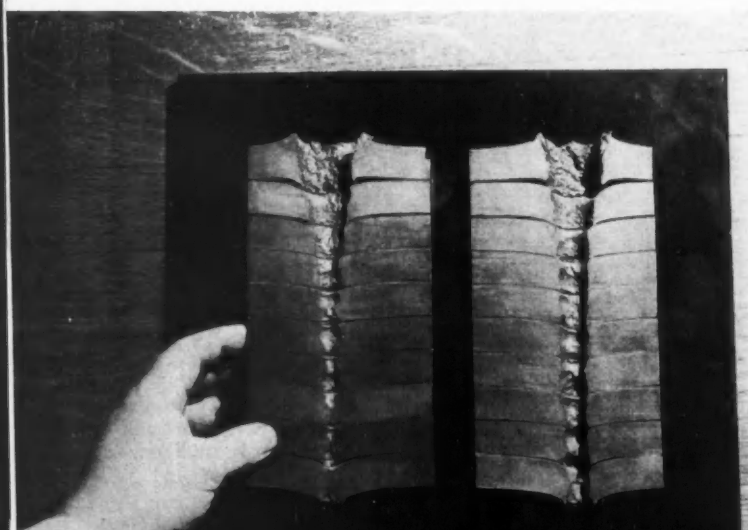
It is a bit difficult to explain the Munroe effect in non-technical language. Perhaps the best rough analogy would be to liken the hollow cone to a concave mirror, focusing the detonation waves of the explosive as the mirror would focus light or heat on one concentrated point.

Strangely enough, although these research results were known to both scientists and practical users of ex-

plosives in this country, it was a foreigner who first induced the Army to experiment with a projectile weapon embodying the Munroe effect. In 1940, after war had already broken out in Europe but before the United States had become directly involved, a young Swiss engineer, Henry Mohaupt, came to this country with the germ of an idea that was to evolve into the now famous "bazooka" rocket charge. He won the support of several progressive-minded Ordnance officers, and later served in the Ordnance Department himself as an enlisted man.

The bazooka rocket was only the first of many weapons in which the Munroe principle was to be incorporated. It is now used in some rockets and artillery shells of various calibers, in rifle grenades, in hand-placed demolition charges, in mines and torpedoes. There is no armor so thick, no concreted bunker so secure, that it cannot be pierced by one form or other of this fiery sword.

➤ THROUGH TEN SLABS *of armor-plate went the explosive, stepped up by nothing more substantial than a little space.*



Submicroscopic Architecture Puts Bounce in Rubber

Our Molecular World

by JOHN G. KIRKWOOD

This talk by the Todd professor of Chemistry, Cornell University, during intermission of a New York Philharmonic Symphony-United States Rubber Company broadcast, is reprinted in CHEMISTRY *for the helpful view of an unfamiliar world it may give to students just starting the subject.*

EVERY MATERIAL object in the world is composed of almost unbelievably tiny units called molecules; and each of these molecules is, in turn, composed of still smaller and simpler units called atoms. The everyday behavior of all of the substances making up the world in which we live—substances such as the leather in your shoes, the glass in your windows, the iron or steel in your stove, and the sugar on your table—the everyday behavior of all of these is determined by the detailed architecture of the molecules of which the substances are composed. Thus the scientist wishes to know how the molecules in question are built up out of the still smaller units, the atoms; and how the atoms are held together, by chemical bonds, in definite structural patterns. Finally, how are the properties of the resulting substances related to the architecture of their molecules? Only when these fundamental questions have been answered can satisfactory replies be found to such everyday questions as: Why is an alloy steel strong? Why is glass brittle? Why can rubber be bent and stretched?

These molecules and atoms of which I speak are almost unimaginably small. An ordinary sized atom would have to be magnified something like a million times before it would be visible to the eye as a tiny speck. But although molecules are much too small to be seen with our eyes, we can build instruments to see them for us and to record their behavior for our study. One such instrument is the *spectrograph*, which measures the wave length—that is to say, the color—of the light emitted and absorbed by molecules and atoms. Such observations, when properly interpreted, provide us with rich information concerning molecules as engineering structures, telling us how strong are the chemical joints between the atoms of which the molecules are composed; and telling us of what kinds of internal motions and vibrations they are capable. Other instruments record on photographic plates the telltale patterns produced when the molecules of a substance deflect beams of X-rays or electrons. These patterns are as characteristic as fingerprints; and from them we learn the size of molecules, the distances between their component atoms, and how they are packed together to make up the materials of our everyday life.

Some molecules contain but few

atoms and possess relatively simple structures. Other giant molecules contain many atoms and are architecturally very complicated. The convenient scale of length in the molecular world is the Ångstrom unit, equal to four-billionths of an inch. Some molecules are only a few Ångstrom units in length, while others are much larger. Thus simple molecules like water, composed of one oxygen atom and two hydrogen atoms, are but a few Ångstroms in length. But giant molecules like those of the proteins, cellulose, and rubber, range in length from hundreds to many thousands of Ångstroms. Some giant molecules, for example, those of the protein of egg white, are shaped somewhat like a football. Others, for example, those of the muscle protein, myosin, and the molecules of natural and synthetic rubbers are long, flexible, and threadlike. Both natural and synthetic rubber owe their characteristic elastic properties to the threadlike structure of their molecules, which have a tendency to get tangled up. But if we apply a pull to a piece of matter composed of the long tangled-up rubber molecules, then the specimen stretches considerably, because the mixed-up network of molecules untangles a bit, even though reluctantly. On the other hand, in crystalline substances, for example, common table salt and the metals, the molecules and atoms are arranged in a most orderly manner, in regular three-dimensional patterns which extend throughout the entire crystal. It is hard to visualize these regular solid patterns of atoms in a crystal. It is a little like the repeated pattern on wallpaper, except that the wallpaper pattern is only two-dimensional or flat, whereas the crystal pattern is three-dimensional or solid.

After our brief glimpse at the structure of molecules, it is natural for us to ask how they are put together to form the materials of the everyday world, and to attempt to discover how it happens that under the same conditions some materials like air are gases, others like water are liquids, while still others like salt and steel are solids.

Two facts furnish the key to the answers to these questions. The first is that molecules, like the sun and the planets, attract each other. The intermolecular attractive force is, however, primarily electrical rather than gravitational in nature. The second important fact is that molecules are in a constant state of motion. Unlike the ordered motions of the planets, the customary motion of molecules is more a chaotic and random dance recalling jive and jitterburg. Of course the motion is on far too small a scale for us to see. But we can feel it. What we feel is heat. When a substance is cold its molecules are dancing sluggishly; when hot, its molecules are dancing briskly.

The outward appearance of a substance, which we recognize as a crystal, liquid, or gas, depends upon a compromise between two sets of influences. On the one hand, *the attractive forces* between the molecules tend to keep the molecules in well-ordered arrays like accurately marching soldiers. On the other hand, *the disordering influence of molecular motion* tends to mix the molecules up like a rioting crowd. At sufficiently low temperatures, the disordering heat motions are weak; the discipline of the

forces between the molecules predominates. Therefore, at low temperatures, we find many substances in the crystalline state, with the molecules arranging themselves in the ordered pattern of a crystal lattice. The structural details of this crystal pattern are at far too fine a scale for observation with the eye. But they can be seen with X-rays. Reflected from a crystal, the X-rays record themselves on a photographic plate in a characteristic pattern from which, with some ingenuity, the structure may be deduced. The beauty and symmetry we admire in the facets of gems and in certain minerals reflect the symmetry and order of the crystal lattice.

As the temperature of a crystal is raised, the pattern of its atoms is disordered more and more by heat motion in the form of sound waves traveling back and forth in the interior of the crystal. These waves can be likened to those which are produced in a violin string by the action of the bow. Fortunately for our comfort, the pitch of these sound waves is so shrill that our ears are not affected. When one continues to heat the substance, the thermal disorder eventually becomes so serious as to throw the regular ranks of the crystal lattice into complete disorder. Then the melting temperature has been reached, and the substance is transformed into a liquid. This transformation is a commonplace phenomenon of our daily life, observed in the melting of snow and ice.

Because of the fluidity of liquids, which allows them to be poured into vessels of any shape, we are accustomed to regard liquids as having no structure. This is not quite true. On the molecular scale, liquids possess a residual trace of regular structure, which, as in the case of crystals, can be observed with the aid of X-rays. X-ray photographs of liquids lack much of the detail of those of crystals and what detail they possess is blurred and indistinct. We are forced to conclude that, although crowded conditions prevail, military order no longer controls the arrangement of the atoms and molecules in a liquid, as it does in a crystal. Nevertheless, each molecule maintains a trace of order with respect to its near neighbors, which locally resembles the more extensive order existing in the crystal lattice. Its efforts to control the pattern of its neighbors are opposed by heat motions, and these efforts only affect a few of its nearest neighbors.

To illustrate some of the foregoing remarks, let us consider the case of water. In an ice crystal, the lattice pattern is an open structure in which each water molecule has four neighbors. When ice melts, the lattice as a whole is destroyed, but each molecule nevertheless keeps four neighbors arranged in a partially collapsed form of the local ice structure. Because of the partial collapse of the open ice structure, liquid water is denser than ice at the melting point. Hence ice floats on liquid water. In fact, this local liquid structure continues to collapse between the melting point and a temperature of four degrees Centigrade. In this temperature interval, therefore, liquid water increases in density. Above four degrees, increasing thermal disorder expands the neighbor structure and the density diminishes with increasing temperature. Were it not for the fact that the open

ice structure collapses on melting, ice would sink in liquid water, as do most crystals in their melts. It would take us too long to explore the consequences of such a state of affairs on geological events, on the weather, and ultimately on our daily lives; but these consequences would be serious and far-reaching, so that the arrangement and behavior of these water molecules, in liquid water and in ice, is actually a matter of direct and practical concern to each one of us.

As the temperature of a liquid is raised, thermal disorder finally completely overpowers molecular attractive forces. The molecules are then torn asunder, and the liquid is transformed into a gas. This we observe when the kettle boils. Of the structure of a gas, little need be said Each molecule leads a solitary but active existence, traveling alone over long stretches of distance and rudely jostling any neighbor which chances in its path.

In addition to satisfying their scientific curiosity, chemists and physicists have been able to put their investigations of molecular structure to good use in ways which could not at first have been anticipated. Apart from their intrinsic scientific interest, studies of molecular structure and of the structure of materials on the molecular scale have contributed directly to the solution of many technical problems. I shall mention only one example. Spectroscopic studies of the modes of vibration of the water molecule and of hydrocarbon molecules have provided basic information needed for the operation of high pressure steam power units, and for the control of the cracking process used in the manufacture of the high octane gasoline which will power your automobile or airplane in the post-war world.

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Size and Shape of Molecules

➤ THE SIZE and shape of large molecules in plastics can now be determined rapidly and visually by the use of two instruments developed and tested in the laboratories of the Polytechnic Institute of Brooklyn. They will be valuable to manufacturers using various types of synthetic rubbers, plastics and fibers by extruding, molding, casting and spinning processes in which the size, shape and weight of the molecules play an important part.

Better rubber tires and shoes, plastic combs, buttons and other articles, and fibers like rayon and nylon, result when the size and shape of the molecules in the materials used are known.

The two new instruments, based on simple visual observations through a microscope, employ the scattering of light to learn about the size, shape and weight of the large molecules in synthetic rubbers and plastics. The principle of the scattering of light was discovered in 1910 by Dr. Albert Einstein, and its application to computing molecular weight and shape of giant molecules was discovered in 1943 by Dr. Peter Debye of Cornell University. Dr. Paul M. Doty, of the Polytechnic Institute staff, is largely responsible for the development of the instruments.

Gold Casts of Protein Particles Studied Under Electron Microscope

Gold Films Aid Plant Disease Study

GOLD FILMS of ultramicroscopic thinness, "cast" over solidified protein particles that are the essence of a virus disease of plants, are helping scientists using the electron microscope to get a better idea of the size and shape of these particles, forever beyond the direct reach of the human eye even when looking through the most powerful of lens combinations.

The new method was worked out in laboratories at the University of Michigan by two physicists, Dr. Robley C. Williams and Dr. Ralph W. G. Wyckoff, who describe it in *Science*.

Objects less than one light wavelength in diameter cannot be made visible in the ordinary-type microscope because they are unable to stop or turn aside light waves. But they can still be photographed when streams of magnetically focussed electrons are substituted for beams of light. However, it is often advantageous to study, not the objects themselves but "casts" formed by depositing some more durable material over them, very much as you could examine last December's snowflakes in June if you caught them on drops of plastic as they fell and kept the molds thus formed.

To get their ultramicroscopic "castings" of tobacco mosaic disease virus particles, Drs. Williams and Wyckoff place a drop of a watery suspension known to contain the virus on a chemically clean glass slide. After the water has evaporated, nothing can be seen on the slide; nevertheless the invisibly tiny bits of solidified virus protein are still there.

They next place their slide in a vacuum chamber, in which a small bit of gold is electrically heated until it goes past its melting-point and becomes a vapor. Some of this evaporated gold falls on the glass and solidifies into a very thin film, just as a sheet of ice would form if water vapor were introduced and the chamber temperature held below freezing-point. Where the gold falls on the virus protein particles, minute hollows are formed, with every detail of the particle structure faithfully reproduced in negative.

The gold film is only about eight Ångstrom units thick. An Ångstrom unit is the light-measurer's "inch"; how short it is can be realized from the fact that light at the limit of high-violet visibility has a wavelength of about 4000 Ångstroms. A gold film only eight Ångstroms thick, therefore, cannot be seen at all, and so cannot be directly picked up.

To get around this difficulty, the two physicists coat the slide with collodion, to which the thin gold will firmly adhere. This collodion film they strip off and place on the stage of the electron microscope. By such roundabout methods they are finally able to get a likeness of the invisible virus particles, faithful in its details as a sculptor's life-mask, into position where beams of the electron microscope can make shadow photographs.

Measurements in Nuclear Physics Are Expressed in These Units

Units of Mass, Charge and Energy

➤ MEASUREMENTS *in the newer physics basic to atomic power are in terms of the units defined here. Both the definitions and the useful conversion table are from the Smyth Report, authorized standard text on things atomic.*

Mass

Since the proton and the neutron are the fundamental particles out of which all nuclei are built, it would seem natural to use the mass of one or the other of them as a unit of mass. The choice would probably be the proton, which is the nucleus of a hydrogen atom. There are good reasons, historical and otherwise, why neither the proton nor the neutron was chosen. Instead, the mass unit used in atomic and nuclear physics is one-sixteenth of the mass of the predominant oxygen isotope, O^{16}, and is equal to 1.6603×10^{-24} gram. Expressed in terms of this unit, the mass of the proton is 1.00758 and the mass of the neutron is 1.00893. (Chemists usually use a very slightly different unit of mass.)

Charge

The unit of electric charge used in nuclear science is the positive charge of the proton. It is equal in magnitude but opposite in sign to the charge on the electron and is therefore often called the electronic charge. One electronic charge is 1.60×10^{-19} coulomb. It may be recalled that a current of one ampere flowing for one second conveys a charge of one coulomb; *i.e.*, one electronic charge equals 1.60×10^{-19} ampere second.

Energy

The energy unit used in nuclear physics is the electron volt, which is defined as equal to the kinetic energy which a particle carrying one electronic charge acquires in falling freely through a potential drop of one volt. It is often convenient to use the million-times greater unit: million electron volt (Mev).

The relationships among the electron volt and other common units of energy are in the following table:

Conversion Table for Energy Units

Multiply	*By*	*To Obtain*
Mev	1.07×10^{-3}	mass units
	1.60×10^{-6}	ergs
	3.83×10^{-14}	g. cal.
	4.45×10^{-20}	kw. hrs.
mass units	9.31×10^{2}	Mev
	1.49×10^{-3}	ergs
	3.56×10^{-11}	g. cal.
	4.15×10^{-17}	kw. hrs.
ergs	6.71×10^{2}	mass units
	6.24×10^{5}	Mev
	2.39×10^{-8}	g. cal.
	2.78×10^{-14}	kw. hrs.
g. cal.	2.81×10^{10}	mass units
	2.62×10^{13}	Mev
	4.18×10^{7}	ergs
	1.16×10^{-6}	kw. hrs.
kw. hrs.	2.41×10^{16}	mass units
	2.25×10^{19}	Mev
	3.60×10^{13}	ergs
	8.60×10^{5}	g. cal.

How Neutron Collisions Generate Plutonium

The Plutonium Problem

Nuclear science, after existing for half a century as one of the most theoretical branches of learning, has suddenly in the five war years had to take up production problems as full-scale, in their way, as those of any blast furnace. The following extracts from the Smyth Report give an indication of the way these problems looked to the men in charge of the project.

Introduction

THE NECESSITY for pushing the design and construction of the full-scale plutonium plant simultaneously with research and development inevitably led to a certain amount of confusion and inefficiency. It became essential to investigate many alternative processes. It became necessary to investigate all possible causes of failure even when the probability of their becoming serious was very small. Now that the Hanford plant is producing plutonium successfully, we believe it is fair to say that a large percentage of the results of investigation made between the end of 1942 and the end of 1944 will never be used—at least not for the originally intended purposes. Nevertheless had the Hanford plant run into difficulties, any one of the now-superfluous investigations might have furnished just the information required to convert failure into success. Even now it is impossible to say that future improvements may not depend on the results of researches that seem unimportant today.

It is estimated that thirty volumes will be required for a complete report of the significant scientific results of researches conducted under the auspices of the Metallurgical Project. Work was done on every item mentioned on the research program presented in the last chapter* In the present account it would be obviously impossible to give more than a brief abstract of all these researches. We believe this would be unsatisfactory and that it is preferable to give a general discussion of the chain-reacting units and separation plants as they now operate, with some discussion of the earlier developments.

The Chain Reaction in a Pile

In Chapter I and other early chapters† we have given brief accounts of the fission process, pile operation, and chemical separation. We shall now review these topics from a somewhat different point of view before describing the plutonium production plants themselves.

The operation of a pile depends on the passage of neutrons through matter and on the nature of the collisions of neutrons with the nuclei encountered. The collisions of principal importance are the following:

I. Collisions in which neutrons are scattered and lose appreciable amounts of energy.

*This interesting list of research projects will appear in a future issue of CHEMISTRY.

† Reprinted in the September and October issues of CHEMISTRY.

(a) Inelastic collisions of fast neutrons with uranium nuclei.

(b) Elastic collisions of fast or moderately fast neutrons with the light nuclei of the moderator material; these collisions serve to reduce the neutron energy to very low (so-called thermal) energies.

II. Collisions in which the neutrons are absorbed.

(a) Collisions which result in fission of nuclei and give fission products and additional neutrons.

(b) Collisions which result in the formation of new nuclei which subsequently disintegrate radioactively (*e.g.*, $_{92}U^{239}$ which produces $_{94}Pu^{239}$).

Only the second class of collision requires further discussion. As regards collisions of type II (a), the most important in a pile are the collisions between neutrons and U-235, but the high-energy fission of U-238 and the thermal fission of Pu-239 also take place. Collisions of type II (b) are chiefly those between neutrons and U-238. Such collisions occur for neutrons of all energies, but they are most likely to occur for neutrons whose energies lie in the "resonance" region located somewhat above thermal energies. The sequence of results of the type II (b) collision is represented as follows:

Any other non-fission absorption processes are important chiefly because they waste neutrons; they occur in the moderator, in U-235, in the coolant, in the impurities originally present, in the fission products, and even in plutonium itself.

Since the object of the chain reaction is to generate plutonium, we would like to absorb all excess neutrons in U-238, leaving just enough neutrons to produce fission and thus to maintain the chain reaction. Actually the tendency of the neutrons to be absorbed by the dominant isotope U-238 is so great compared to their tendency to produce fission in the 140-times-rarer U-235 that the principal design effort had to be directed toward favoring the fission (as by using a moderator, a suitable lattice, materials of high purity, etc.,) in order to maintain the chain reaction.

The publication by the War Department in August 1945 of the Account of the Development of Methods of Using Atomic Energy, by H. D. Smyth of Princeton University, marked one of the great steps of all time in the advance of nuclear chemistry and physics. In order to bring the Smyth Report to the attention of its readers, Chemistry devoted its entire September issue to extracts from it, and in the October issue reprinted the main facts about the chemical properties of the new element Plutonium, so far as they have been revealed. The quotations in this issue explain the technical problems involved in manufacture of the element.

$$_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{92}U^{239} + \text{gamma rays}$$

$$_{92}U^{239} \xrightarrow[23\ \text{min.}]{} {}_{93}Np^{239} + {}_{-1}e^{0}$$

$$_{93}Np^{239} \xrightarrow[2.3\ \text{days}]{} {}_{94}Pu^{239} + {}_{-1}e^{0} + \text{gamma rays}$$

Life History of One Generation of Neutrons

ALL THE chain-reacting piles designed by the Metallurgical Laboratory or with its co-operation consist of four categories of material—the uranium metal, the moderator, the coolant, and the auxiliary materials such as water tubes, casings of uranium, control strips or rods, impurities, etc. All the piles depend on stray neutrons from spontaneous fission or cosmic rays to initiate the reaction.

Suppose that the pile were to be started by simultaneous release (in the uranium metal) of N high-energy neutrons. Most of these neutrons originally have energies above the threshold energy of fission of U-238. However, as the neutrons pass back and forth in the metal and moderator, they suffer numerous inelastic collisions with the uranium and numerous elastic collisions with the moderator, and all these collisions serve to reduce the energies below that threshold. Specifically, in a typical graphite-moderated pile a neutron that has escaped from the uranium into the graphite travels on the average about 2.5 cm between collisions and makes on the *average* about 200 elastic collisions before passing from the graphite back into the uranium. Since at each such collision a neutron loses on the average about one-sixth of its energy, a one Mev neutron is reduced to thermal energy (usually taken to be 0.025 electron volt) considerably before completing a single transit through the graphite. There are, of course, many neutrons that depart from this average behavior, and there will be enough fissions produced by fast neutrons to enhance slightly the number of neutrons present. The enhancement may be taken into account by multiplying the original number of neutrons N by a factor ε which is called the fast-fission effect or the fast-multiplication factor.

As the average energy of the $N\varepsilon$ neutrons present continues to fall, inelastic collision in the uranium becomes unimportant, the energy being reduced essentially only in the moderator. However, the chance of non-fission absorption (resonance capture) in U-238 becomes significant as the intermediate or resonance energy region is reached. Actually quite a number of neutrons in this energy region will be absorbed regardless of choice of lattice design. The effect of such capture may be expressed by multiplying $N\varepsilon$ by a factor p, (which is always less than one) called the "resonance escape probability" which is the probability that a given neutron starting with energy above the resonance region will reach thermal energies without absorption in U-238. Thus from the original N high-energy neutrons we obtain $N\varepsilon p$ neutrons of thermal energy.

Once a neutron has reached thermal energy the chance of its losing more energy by collision is no greater than the chance of its gaining energy. Consequently the neutrons will remain at this average energy until they are absorbed. In the thermal-energy region the chance for absorption of the neutron by the moderator, the coolant and the auxiliary materials is greater than at higher energies. At any rate it is found that we introduce little error into our calculations by assum-

ing all such unwanted absorption takes place in this energy region. We now introduce a factor f, called the thermal utilization factor, which is defined as the probability that a given thermal neutron will be absorbed in the uranium. Thus from the original N fast neutrons we have obtained $N\epsilon pf$ thermal neutrons which are absorbed by uranium.

Although there are several ways in which the normal mixture of uranium isotopes can absorb neutrons, the reader may recall that we defined in a previous chapter a quantity η, which is the number of fission neutrons produced for each thermal neutron absorbed in uranium regardless of the details of the process. If, therefore, we multiply the number of thermal neutrons absorbed in uranium, $N\epsilon pf$, by η, we have the number of new high speed neutrons generated by the original N high speed neutrons in the course of their lives. If $N\epsilon pf\eta$ is greater than N, we have a chain reaction and the number of neutrons is continually increasing. Evidently the product $\epsilon pf\eta = k_\infty$, the multiplication factor already defined in Chapter IV.

Note that no mention has been made of neutrons escaping from the pile. Such mention has been deliberately avoided since the value of k_∞ as defined above applies to an infinite lattice. From the known values of k_∞ and the fact that these piles do operate, one finds that the percentage of neutrons escaping cannot be very great. As we saw in Chapter II, the escape of neutrons becomes relatively less important as the size of the pile increases. If it is necessary to introduce in the pile a large amount of auxiliary material such as cooling-system pipes, it is necessary to build a somewhat larger pile to counteract the increase in absorption.

To sum up, a pile operates by reducing high-energy neutrons to thermal energies by the use of a moderator-lattice arrangement, then allowing the thermal-energy neutrons to be absorbed by uranium, causing fission which regenerates further high-energy neutrons. The regeneration of neutrons is aided slightly by the fast neutron effect; it is impeded by resonance absorption during the process of energy reduction, by absorption in graphite and other materials, and by neutron escape.

Reaction Products and the Multiplication Factor

Even at the high power level used in the Hanford pile, only a few grams of U-238 and of U-235 are used up per day per million grams of uranium present. Nevertheless the effects of these changes are very important. As the U-235 is becoming depleted, the concentration of plutonium is increasing. Fortunately, plutonium itself is fissionable by thermal neutrons and so tends to counterbalance the decrease of U-235 as far as maintaining the chain reaction is concerned. However, other fission products are being produced also. These consist typically of unstable and relatively unfamiliar nuclei so that it was originally impossible to predict how great an undesirable effect they would have on the multiplication constant. Such deleterious effects are called poisoning. In spite of a great deal of preliminary study of fission products, an unforeseen poisoning effect of this kind very nearly prevents operation of the Hanford piles, as we shall see later.

Reaction Products and the Separation Problem

There are two main parts of the plutonium production process at Hanford: actual production in the pile, and separation of the plutonium from the uranium slugs in which it is formed. We turn now to a discussion of the second part, the separation process.

The uranium slugs containing plutonium also contain other elements resulting from the fission of U-235. When a U-235 nucleus undergoes fission, it emits one or more neutrons and splits into two fragments of comparable size and of total mass 235 or less. Apparently fission into precisely equal masses rarely occurs, the most abundant fragments being a fragment of mass number between 134 and 144 and a fragment of mass number between 100 and 90. Thus there are two groups of fission products: a heavy group with mass numbers extending approximately from 127 to 154, and a light group from approximately 115 to 83. These fission products are in the main unstable isotopes of the thirty or so known elements in these general ranges of mass number. Typically they decay by successive beta emissions accompanied by gamma radiation finally to form known stable nuclei. The half-lives of the various intermediate nuclei range from fractions of a second to a year or more; several of the important species have half-lives of the order of a month or so. About twenty different elements are present in significant concentration. The most abundant of these comprises slightly less than 10 per cent of the aggregate.

In addition to radioactive fission products, U-239 and Np-239 (intermediate products in the formation of plutonium) are present in the pile and are radioactive. The concentrations of all these products begin to build up at the moment the pile starts operating. Eventually the rate of radioactive decay equals the rate of formation so that the concentrations become constant. For example, the number of atoms of U-239 produced per second is constant for a pile operating at a fixed power level. According to the laws of radioactive disintegration, the number of U-239 atoms disappearing per second is proportional to the number of such atoms present and is thus increasing during the first few minutes or hours after the pile is put into operation. Consequently there soon will be practically as many nuclei disintegrating each second as are formed each second. Equilibrium concentrations for other nuclei will be approached in similar manner, the equilibrium concentration being proportional to the rate of formation of the nucleus and to its half-life. Products which are stable or of extremely long half-life (*e.g.*, plutonium) will steadily increase in concentration for a considerable time. When the pile is stopped, the radioactivity of course continues, but at a continually diminishing absolute rate. Isotopes of very short half-life may "drop out of sight" in a few minutes or hours; others of longer half-life keep appreciably active for days or months. Thus at any time the concentrations of the various products in a recently stopped pile depend on what the power level was, on how long the pile ran, and on how long it has been shut down. Of course, the longer the

pile has run, the larger is the concentration of plutonium and (unfortunately) the larger is the concentration of long-lived fission products. The longer the "cooling" period, *i.e.*, the period between removal of material from the pile and chemical treatment, the lower is the radiation intensity from the fission products. A compromise must be made between such considerations as the desire for a long running and cooling time on the one hand and the desire for early extraction of the plutonium on the other hand.

Tables can be prepared showing the chemical concentrations of plutonium and the various fission products as functions of power level, length of operation, and length of cooling period. The half life of the U-239 is so short that its concentration becomes negligible soon after the pile shuts down. The neptunium becomes converted fairly rapidly to plutonium. Of course, the total weight of fission products, stable and unstable, remains practically constant after the pile is stopped. For the Clinton and Hanford operating conditions the maximum plutonium concentration attained is so small as to add materially to the difficulty of chemical separation.

Chemical Separation Process

The problem then is to make a chemical separation at the daily rate of, say, several grams of plutonium from several thousand grams of uranium contaminated with large amounts of dangerously radioactive fission products comprising twenty different elements. The problem is especially difficult as the plutonium purity requirements are very high indeed.

Four types of method for chemical separation were examined: volatility, absorption, solvent extraction, and precipitation. The work on absorption and solvent extraction methods has been extensive and such methods may be increasingly used in the main process or in waste recovery, but the Hanford Plant was designed for a precipitation process.

The phenomena of co-precipitation, *i.e.*, the precipitation of small concentrations of one element along with a "carrier" precipitate of some other element, had been commonly used in radioactive chemistry, and was adopted for plutonium separation. The early work on plutonium chemistry, confined as it was to minute amounts of the element, made great use of precipitation reactions from which solubility properties could be deduced. It was therefore natural that precipitation methods of separation were the most advanced at the time when the plant design was started. It was felt that, should the several steps in the separations process have to be developed partly by the empirical approach, there would be less risk in the scale-up of a precipitation process than, for example, of one involving solid-phase reactions. In addition, the precipitaiton processes then in mind could be broken into a sequence of repeated operations (called cycles), thereby limiting the number of different equipment pieces requiring design and allowing considerable process change without equipment change. Thus, while the basic plant design was made with one method in mind,

the final choice of a different method led to no embarrassments.

Most of the precipitation processes which have received serious consideration made use of an alternation between the (IV) and (VI) oxidation states of plutonium. Such processes involve a precipitation of plutonium (IV) with a certain compound as a carrier, then dissolution of the precipitate, oxidation of the plutonium to the (VI) state, and reprecipitation of the carrier compound while the plutonium (VI) remains in solution. Fission products which are not carried by these compounds remain in solution when plutonium (IV) is precipitated. The fission products which carry are removed from the plutonium when it is in the (VI) state. Successive oxidation-reduction cycles are carried out until the desired decontamination is achieved. (The process of elimination of the fission products is called decontamination and the degree of elimination is tested by measuring the change in radioactivity of the material.)

Combination Processes

It is possible to continue to combine or couple the various types of process. Some advantages may be gained in this way since one type of process may supplement another. For example, a process which gives good decontamination might be combined advantageously with one which, while inefficient for decontamination, would be very efficient for separation from uranium.

At the time when it became necessary to decide on the process to serve as the basis for the design of the Hanford plant (June 1943), the choice, for reasons given above, was limited to precipitation processes and clearly lay between two such processes. However, the process as finally chosen actually represented a combination of the two.

The success of the separation process at Hanford has exceeded all expectations. The high yields and decontamination factors and the relative ease of operation have amply demonstrated the wisdom of its choice as a process. This choice was based on a knowledge of plutonium chemistry which had been gleaned from less than a milligram of plutonium. Further developments may make the present Hanford process obsolete, but the principal goal, which was to have a workable and efficient process for use as soon as the Hanford piles were delivering plutonium, has been attained.

The Argonne Laboratory

➤ THE ARGONNE LABORATORY was constructed early in 1943 outside Chicago. The site originally intended for a pilot plant, was later considered to be too near the city and was used for reconstructing the so-called West Stands pile which was originally built on the University of Chicago grounds and which was certainly innocuous. Under the direction of E. Fermi and his colleagues, H. L. Anderson, W. H. Zinn, G. Weil, and others, this pile has served as a prototype unit for studies of thermal stability, controls, instruments, and shielding, and as a neutron source for materials testing and neutron-physics studies. Furthermore, it has proved valuable as a training school for plant operators. More recently a heavy-water pile (see below) has been constructed there.

The first Argonne pile, a graphite-

uranium pile, need not be described in detail. The materials and lattice structure are nearly identical to those which were used for the original West Stands pile. The pile is a cube; it is surrounded by a shield and has controls and safety devices somewhat similar to those used later at Clinton. It has no cooling system and is normally run at a power level of only a few kilowatts. It has occasionally been run at high-power levels for very brief periods. Considering that it is merely a reconstruction of the first chain-reacting unit ever built, it is amazing that it has continued in operation for more than two years without developing any major troubles.

One of the most valuable uses of the Argonne pile has been the measurement of neutron-absorption cross sections of a great variety of elements which might be used in piles as structural members, etc., or which might be present in pile materials as impurities. These measurements are made by observing the change in the controls necessary to make k_{eff} equal to 1.00 when a known amount of the substance under study is inserted at a definite position in the pile. The results obtained were usually expressed in terms of "danger coefficients."

An opening at the top of the pile lets out a very uniform beam of thermal neutrons that can be used for exponential-pile experiments, for direct measurements of absorption cross sections, for Wilson cloud chamber studies, etc.

An interesting phenomenon occurring at the top of the pile is the production of a beam or flow of "cold" neutrons. If a sufficient amount of graphite is interposed between the upper surface of the pile and an observation point a few yards above, the neutron energy distribution is found to correspond to a temperature much lower than that of the graphite. This is presumed to be the result of a preferential transmission by the (crystalline) graphite of the slowest ("coldest") neutrons, whose quantum-mechanical wavelength is great compared to the distance between successive planes in the graphite crystals.

More recently a pile using heavy water as moderator was constructed in the Argonne Laboratory. The very high intensity beam of neutrons produced by this pile has been found well-suited to the study of "neutron optics," *e.g.*, reflection and refraction of neutron beams as by graphite.

A constant objective of the Argonne Laboratory has been a better understanding of nuclear processes in uranium, neptunium, and plutonium. Repeated experiments have been made to improve the accuracy of constants such as thermal-fission cross sections of U-235, U-238, and Pu-239, probabilities of non-fission neutron absorption by each of these nuclei, and number of neutrons emitted per fission.

On the Back Cover

➤ THE SHOULDER PATCH *of the Manhattan Engineer District, worn by Army personnel working on the atomic bomb project, gives the impression of a mysterious question mark.*

The Clinton Plant

In chapter VI* we mentioned plans for a "pilot" plant for production of plutonium to be built at the Clinton site in Tennessee. By January 1943, the plans for this project were well along; construction was started soon afterward. M. D. Whitaker was appointed director of the Clinton Laboratories. The pilot-plant plans were made co-operatively by du Pont and the Metallurgical Laboratory; construction was carried out by du Pont; plant operation was maintained by the University of Chicago as part of the Metallurgical Project.

The main purposes of the Clinton plant were to produce some plutonium and to serve as a pilot plant for chemical separation. As regards research, the emphasis at Clinton was on chemistry and biological effects of radiations. A large laboratory was provided for chemical analysis, for research on purification methods, for fission-product studies, for development of intermediate-scale extraction and decontamination processes, etc. Later a "hot laboratory," *i.e.*, a laboratory for remotely-controlled work on highly radioactive material, was provided. There is also an instrument shop and laboratory that has been used very actively. There are facilities for both clinical and experimental work of the health division, which has been very active. There is a small physics laboratory in which some important work was done using higher neutron intensities than were available at the Argonne Laboratory. The principal installations constructed at the Clinton Laboratory site were the pile and the separation plant; these are briefly described below.

The Clinton Pile

In any steadily operating pile the effective multiplication factor k must be kept at one, whatever the power level. The best k_∞ that had been observed in a uranium-graphite lattice could not be achieved in a practical pile because of neutron leakage, cooling system, cylindrical channels for the uranium, protective coating on the uranium, and other minor factors. Granted air-cooling and a maximum safe temperature for the surface of the uranium, a size of pile had to be chosen that could produce 1000 kw. The effective k would go down with rising temperature but not sufficiently to be a determining factor. Though a sphere was the ideal shape, practical considerations recommended a rectangular block.

The Clinton pile consists of a cube of graphite containing horizontal channels filled with uranium. The uranium is in the form of metal cylinders protected by gas-tight casings of aluminum. The uranium cylinders or slugs may be slid into the channels in the graphite; space is left to permit cooling air to flow past, and to permit pushing the slugs out at the back of the pile when they are ready for processing. Besides the channels for slugs there are various other holes through the pile for control rods, instruments, etc.

The Clinton pile was considerably larger than the first pile at Chicago. More important than the increased size of the Clinton pile were its cooling system, heavier shields, and means

* See October issue of Chemistry.

for changing the slugs. The production goal of the Clinton plant was set at a figure which meant that the pile should operate at a power level of 1000 kw.

The instrumentation and controls are identical in principle to those of the first pile. Neutron intensity in the pile is measured by a BF_3 ionization chamber and is controlled by boron steel rods that can be moved in and out of the pile, thereby varying the fraction of neutrons available to produce fission.

In spite of impressiveness of the array of instruments and safety devices, the most striking feature of the pile is the simplicity of operation. Most of the time the operators have nothing to do except record the readings of various instruments.

The Separation Plant

Here, as at Hanford, the plutonium processes have to be carried out by remote control and behind thick shields. The separation equipment is housed in a series of adjacent cells having heavy concrete walls. These cells form a continuous structure (canyon) which is about 100 feet long and is two-thirds buried in the ground. Adjacent to this canyon are the control rooms, analytical laboratories, and a laboratory for further purification of the plutonium after it has been decontaminated to the point of comparative safety.

Uranium slugs that have been exposed in the pile are transferred under water to the first of these cells and are then dissolved. Subsequent operations are performed by pumping solutions or slurries from one tank or centrifuge to another.

Performance of Clinton Pile

The Clinton pile started operating on November 4, 1943 and within a few days was brought up to a power level of 500 kw at a maximum slug surface temperature of 110°C. Improvements in the air circulation and an elevation of the maximum uranium surface temperature to 150°C brought the power level up to about 800 kw, where it was maintained until the spring of 1944. Starting at that time, a change was made in the distribution of uranium, the change being designed to level out the power distribution in the pile by reducing the amount of metal near the center relative to that further out and thereby to increase the average power level without anywhere attaining too high a temperature. At the same time improvements were realized in the sealing of the slug jackets, making it possible to operate the pile at higher temperature. As a result, a power level of 1800 kw was attained in May, 1944; this was further increased after the installation of better fans in June 1944.

Thus the pile performance of June 1944 considerably exceeded expectations. In ease of control, steadiness of operation, and absence of dangerous radiation, the pile has been most satisfactory. There have been very few failures attributable to mistakes in design or construction.

The pile itself was simple both in principle and in practice. Not so the plutonium-separation plant. The step from the first chain-reacting pile to the Clinton pile was reasonably predictable; but a much greater and more uncertain step was required in the case of the separation process, for the Clinton separation plant was designed

on the basis of experiments using only microgram amounts of plutonium.

Nevertheless, the separation process worked! The first batch of slugs from the pile entered the separation plant on December 20, 1943. By the end of January 1944, metal from the pile was going to the separation plant at the rate of ½ ton per day. By February 1st, 1944, 190 mg of plutonium had been delivered and by March 1st, 1944, several grams had been delivered. Furthermore, the efficiency of recovery at the very start was about 50 per cent, and by June 1944 it was between 80 and 90 per cent.

During this whole period there was a large group of chemists at Clinton working on improving the process and developing it for Hanford. The Hanford problem differed from that at Clinton in that much higher concentrations of plutonium were expected. Furthermore, though the chemists were to be congratulated on the success of the Clinton plant, the process was complicated and expensive. Any improvements in yield or decontamination or in general simplification were very much to be sought.

Besides the proving of the pile and the separation plant and the production of several grams of plutonium for experimental use at Chicago, Clinton, and elsewhere, the Clinton Laboratories have been invaluable as a training and testing center for Hanford, for medical experiments, pile studies, purification studies, and physical and chemical studies of plutonium and fission products.

As typical of the kind of problems tackled there and at Chicago, the following problems—listed in a single routine report for May 1944— are pertinent:

Problems Closed Out during May, 1944:

- Search for New Oxidizing Agent
- Effect of Radiation on Water and Aqueous Solutions
- Solubility of Plutonium Peroxide
- Plutonium Compounds Suitable for Shipment
- Fission Product Distribution in Plant Process Solutions
- Preliminary Process Design for Adsorption Extraction
- Adsorption Semi-Works Assistance
- Completion of Adsorption Process Design

New Problems Assigned during May, 1944:

- New Product Analysis Method
- Effect of Radiation on Graphite
- Improvement in Yield
- New Pile Explorations
- Waste Uranium Recovery
- Monitoring 205 Stack Gases
- Disposal of Active Waste Solutions
- Spray Cooling of X Pile
- Assay Training Program
- Standardization of Assay Methods
- Development of Assay Methods
- Shielded Apparatus for Process Control Assays
- Cloud Chamber Experiment
- Alpha Particles from U-235
- Radial Product Distribution
- Diffraction of Neutrons

➤ COMMUNITIES OF PEOPLE *working on nuclear projects had to be established in remote places. On pages two and three of this issue are pictures of typical scenes at Hanford, Washington, and Oak Ridge, Tennessee.*

The Hanford Plant

➤ IT IS BEYOND the scope of this report to give any account of the construction of the Hanford Engineer Works, but it is to be hoped that the full story of this extraordinary enterprise and the companion one, the Clinton Engineer Works, will be published at some time in the future. The Hanford site was examined by representatives of General Groves and of du Pont at the end of 1942, and use of the site was approved by General Groves after he had inspected it personally. It was on the west side of the Columbia River in central Washington north of Pasco. In the early months of 1943 a two-hundred square mile tract in this region was acquired by the government (by lease or purchase) through the Real Estate Division of the Office of the Chief of Engineers. Eventually an area of nearly a thousand square miles was brought under government control. At the time of acquisition of the land there were a few farms and two small villages, Hanford and Richland, on the site, which was otherwise sagebrush plains and barren hills. On the 6th of April, 1943, ground was broken for the Hanford construction camp. At the peak of activity in 1944, this camp was a city of 60,000 inhabitants, the fourth largest city in the state. Now, however, the camp is practically deserted as the operating crew is housed at Richland.

Work was begun on the first of the Hanford production piles on June 7, 1943, and operation of the first pile began in September 1944. The site was originally laid out for five piles, but the construction of only three has been undertaken. Besides the piles, there are, of course, plutonium separation plants, pumping stations and water-treatment plants. There is also a low power chain-reacting pile for material testing. Not only are the piles themselves widely spaced for safety—several miles apart—but the separation plants are well away from the piles and from each other. All three piles were in operation by the summer of 1945.

Canning and Corrosion

No one who lived through the period of design and construction of the Hanford plant is likely to forget the "canning" problem, *i.e.*, the problem of sealing the uranium slugs in protective metal jackets. On periodic visits to Chicago the writer could roughly estimate the state of the canning problem by the atmosphere of gloom or joy to be found around the laboratory. It was definitely not a simple matter to find a sheath that would protect uranium from water corrosion, would keep fission products out of the water, would transmit heat from the uranium to the water, and would not absorb too many neutrons. Yet the failure of a single can might conceivably require shut-down of an entire operating pile.

Attempts to meet the stringent requirements involved experimental work on electroplating processes, hot-dipping processes, cementation-coating processes, corrosion-resistant alloys of uranium, and mechanical jacketing or canning processes. Mechanical jackets or cans of thin aluminum were feasible from the nuclear point of view and were chosen early as the most likely solution of the problem. But the problem of getting a uniform, heat-conducting bond between the uranium

and the surrounding aluminum, and the problem of effecting a gas-tight closure for the can both proved very troublesome. Development of alternative methods had to be carried along up to the last minute, and even up to a few weeks before it was time to load the uranium slugs into the pile there was no certainty that any of the processes under development would be satisfactory. A final minor but apparently important modification in the preferred canning process was adopted in October 1944, after the first pile had begun experimental operation. By the summer of 1945, there had been no can failure reported.

Present Status of Hanford Plants

In the course of the fall of 1944 and the early months of 1945 the second and third Hanford piles were finished and put into operation, as were the additional chemical separation plants. There were, of course, some difficulties; however, none of the fears expressed as to canning failure, film formation in the water tubes, or radiation effects in the chemical processes, have turned out to be justified. As of early summer 1945 the piles are operating at designed power, producing plutonium, and heating the Columbia River. The chemical plants are separating the plutonium from the uranium and from the fission products with better efficiency than had been anticipated. The finished product is being delivered. How it can be used is the subject of Chapter XII.*

* The Chapter on the Atomic Bomb—to appear in a future issue of CHEMISTRY.

The Work on Heavy Water

IN PREVIOUS CHAPTERS there have been references to the advantages of heavy water as a moderator. It is more effective than graphite in slowing down neutrons and it has a smaller neutron absorption than graphite. It is therefore possible to build a chain-reacting unit with uranium and heavy water and thereby to attain a considerably higher multiplication factor, k, and a smaller size than is possible with graphite. But one must have the heavy water.

In the spring of 1943 the Metallurgical Laboratory decided to increase the emphasis on experiments and calculations aimed at a heavy water pile. To this end a committee was set up under E. Wigner, a group under A. A. Vernon was transferred from Columbia to Chicago, and H. D. Smyth, who had just become associate director of the Laboratory, was asked to take general charge. (As it turned out, this group was active for only about six months.)

The first function of this group was to consider in what way heavy water could best be used to insure the overall success of the Metallurgical Project, taking account of the limited production schedule for heavy water that had been already authorized.

It became apparent that the production schedule was so low that it would take two years to produce enough heavy water to "moderate" a fair-sized pile for plutonium production. On the other hand, there might be enough heavy water to moderate a small "laboratory" pile, which could furnish information that might be valuable. In any event, during the summer of 1943 so great were the uncertainties as to

the length of the war and as to the success of the other parts of the DSM project that a complete study of the possibilities of heavy-water piles seemed desirable. Either the heavy-water production schedule might be stepped up or the smaller, experimental pile might be built. An intensive study of the matter was made during the summer of 1943 but in November it was decided to curtail the program and construction was limited to a 250-kw pile located at the Argonne site.

The Argonne Heavy-Water Pile

Perhaps the most striking aspect of the uranium and heavy-water pile at the Argonne is its small size. Even with its surrounding shield of concrete it is relatively small compared to the uranium-graphite piles.

By May 15, 1944, the Argonne uranium and heavy-water pile was ready for test. With the uranium slugs in place, it was found that the chain reaction in the pile became self sustaining when only three-fifths of the heavy water had been added. The reactivity of the pile was so far above expectations that it would have been beyond the capacity of the control rods to handle if the remainder of the heavy water had been added. To meet this unusual and pleasant situation some of the uranium was removed and extra control rods were added.

With these modifications it was possible to fill the tank to the level planned. By July 4, 1944, W. H. Zinn reported that the pile was running satisfactorily at 190 kw, and by August 8, 1944, he reported that it was operating at 300 kw.

In general the characteristics of this pile differed slightly from those of comparable graphite piles. This pile takes several hours to reach equilibrium. It shows small (less than 1 per cent) but sudden fluctuations in power level, probably caused by bubbles in the water. It cannot be shut down as completely or as rapidly as the graphite pile because of the tendency of delayed gamma rays to produce (from the heavy water) additional neutrons. As anticipated, the neutron density at the center is high. The shields, controls, heat exchanger, etc., have operated satisfactorily.

The Health Division

➤ THE MAJOR OBJECTIVE of the health group was in a sense a negative one, to insure that no one concerned suffered serious injury from the peculiar hazards of the enterprise. Medical case histories of persons suffering serious injury or death resulting from radiation were emphatically not wanted.

To achieve its objective the health group worked along three major lines:

1) Adoption of pre-employment physical examinations and frequent re-examinations, particularly of those exposed to radiation.

2) Setting of tolerance standards for radiation doses and development of instruments measuring exposure of personnel; giving advice on shielding, etc.; continually measuring radiation intensities at various locations in the plants; measuring contamination of clothes, laboratory desks, waste water, the atmosphere, etc.

3) Carrying out research on the effects of direct exposure of persons and animals to various types of radiation, and on the effects of ingestion

and inhalation of the various radioactive or toxic materials such as fission products, plutonium and uranium.

Routine Examinations

The white blood-corpuscle count was used as the principal criterion as to whether a person suffered from overexposure to radiation. A number of cases of abnormally low counts were observed and correlated with the degree of overexposure. Individuals appreciably affected were shifted to other jobs or given brief vacations; none have shown permanent ill effects.

At the same time it was recognized that the white blood-corpuscle count is not an entirely reliable criterion. Some work on animals indicated that serious damage might occur before the blood count gave any indication of danger. Accordingly, more elaborate blood tests were made on selected individuals and on experimental animals in the hope of finding a test that would give an earlier warning of impending injury.

Instruments for Radiation Measurements

The Health Division had principal responsibility for the development of pocket meters for indicating the extents of exposure of persons. The first of these instruments was a simple electroscope about the size and shape of a fountain pen. Such instruments were electrostatically charged at the start of each day and were read at the end of the day. The degree to which they became discharged indicated the total amount of ionizing radiation to which they have been exposed. Unfortunately they were none too rugged and reliable, but the error of reading was nearly always in the right direction—*i.e.*, in the direction of overstating the exposure. At an early date the practice was established of issuing two of these pocket meters to everyone entering a dangerous area. A record was kept of the readings at the time of issuance and also when the meters were turned in. The meters themselves were continually although gradually improved. The Health Division later introduced "film badges," small pieces of film worn in the identification badge, the films being periodically developed and examined for radiation blackening.

The Health Division co-operated with the Physics Division in the development and use of various other instruments. There was "Sneezy" for measuring the concentration of radioactive dust in the air and "Pluto" for measuring α-emitting contamination (usually plutonium) of laboratory desks and equipment. Counters were used to check the contamination of laboratory coats before and after the coats were laundered. At the exit gates of certain laboratories concealed counters sounded an alarm when someone passed whose clothing, skin or hair was contaminated. In addition, routine inspections of laboratory areas were made.

One of the studies made involved meteorology. It became essential to know whether the stack gases (at Clinton and at Hanford) would be likely to spread radioactive fission products in dangerous concentrations. Since the behavior of these gases is very dependent on the weather, studies were made at both sites over a period of many months, and satisfactory stack operation was specified.

Research

Since both the scale and the variety of the radiation hazards in this enterprise were unprecedented, all reasonable precautions were taken; but no sure means were at hand for determining the adequacy of the precautions. It was essential to supplement previous knowledge as completely as possible. For this purpose, an extensive program of animal experimentation was carried out along three main lines: (1) exposure to neutron, alpha, beta and gamma radiation; (2) ingestion of uranium, plutonium and fission products; (3) inhalation of uranium, plutonium and fission products. Under the general direction of Dr. Stone these experiments were carried out at Chicago, Clinton and the University of California principally by Dr. Cole and Dr. Hamilton. Extensive and valuable results were obtained.

Summary

▶ Both space and security restrictions prevent a detailed report on the work of the laboratories and plants concerned with plutonium production.

Two types of neutron absorption are fundamental to the operation of the plant: one, neutron absorption in U-235 resulting in fission, maintains the chain reaction as a source of neutrons; the other, neutron absorption in U-238 leads to the formation of plutonium, the desired product.

The course of a nuclear chain reaction in a graphite-moderated heterogeneous pile can be described by following a single generation of neutrons. The original fast neutrons are slightly increased in number by fast fission, reduced by resonance absorption in U-238 and further reduced by absorption at thermal energies in graphite and other materials and by escape; the remaining neutrons, which have been slowed in the graphite, cause fission in U-235, producing a new generation of fast neutrons similar to the previous generation.

The product, plutonium, must be separated by chemical processes from a comparable quantity of fission products and a much larger quantity of uranium. Of several possible separation processes the one chosen consists of a series of reactions including precipitating with carriers, dissolving, oxidizing and reducing.

The chain reaction was studied at low power at the Argonne Laboratory beginning early in 1943. Both chain reaction and chemical separation processes were investigated at the Clinton Laboratories beginning in November 1943, and an appreciable amount of plutonium was produced there.

Construction of the main production plant at Hanford, Washington, was begun in 1943 and the first large pile went into operation in September 1944. The entire plant was in operation by the summer of 1945 with all chain-reacting piles and chemical-separation plants performing better than had been anticipated.

Extensive studies were made on the use of heavy water as a moderator and an experimental pile containing heavy water was built at the Argonne Laboratory. Plans for a production plant using heavy water were given up.

The Health Division was active along three main lines.

Plan for Index of 500,000 Chemical Formulas

Chemical Abstracting Active

➤ THE NATION that is vigilant in science and technology wins wars, and despite wartime conditions American chemists have been kept informed of progress, even in Europe, in their field, Dr. E. J. Crane, of Ohio State University, editor of "Chemical Abstracts," told the Maryland Section of the American Chemical Society.

As an example, 3593 abstracts of current German patents were published during the last year among a total of 11,494 chemical patents abstracted by the American Chemical Society's international reporting service.

"Advances in science are made by steps," Dr. Crane explained. "The effective starting point for the next step must always be the advanced position reached by all workers."

"Chemical Abstracts," published by the American Chemical Society at Ohio State, is a key to the world's chemical literature, and a most essential tool in chemical research.

The staff of the publication reads 4,000 scientific, technical, and trade periodicals in 31 languages and appearing in many parts of the world, and in a normal year prepares 45,000 abstracts of scientific reports of experimental chemical work, Dr. Crane said. These are published in classified form, together with annual indexes which alone make up some 1,500 large pages of fine print.

"It has been of special importance to keep American chemists informed as to chemical progress during the war," he continued. " 'Chemical Abstracts' has managed to do this despite the difficulties in getting scientific information out of many countries, as those of Europe, under wartime conditions.

"There has been a falling off of only about one-third in the publication of scientific and technical literature with a bearing on chemistry. 'Chemical Abstracts' published 45,414 abstracts of papers in 1939, and the corresponding figure for 1944 was 30,440 abstracts.

"Scientific publication has continued even in such hard-hit countries as France. Even though much wartime scientific work is not set down in print, there is nevertheless a great quantity of new information which can be learned and made available to aid in the continuing research of others. Progress is made by such cooperation; little could be accomplished by any individual or small group of chemists if long cut off from the work of other chemists."

Microfilm copying now is being used increasingly in distribution of scientific information, Dr. Crane added, and "hundreds of pages of printed material can be put on a microfilm roll no larger than a small spool of thread. Microfilm reading devices are widely distributed."

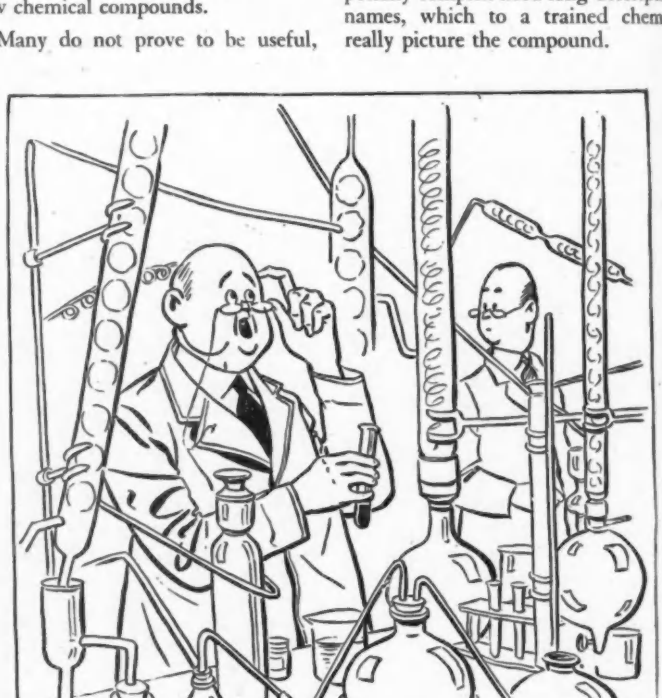
Dr. Crane announced a plan "for recording the 500,000 chemical compounds prepared or studied during the last 25 years, by use of chemical

formulas systematcially arranged. This 25-year Collective Formula Index will be a great storehouse of useful information for the furtherance of research.

"Every science has need of technical terms peculiar to its field," the speaker explained. "These are particularly numerous in chemistry because in a normal year chemists prepare, study and describe about 25,000 new chemical compounds.

'Many do not prove to be useful, but there is always the possibility that one of these compounds will prove to be a penicillin, a sulfanilamide, an insulin, or will serve as a dye, explosive, photographic sensitizer, analytical reagent, disinfectant, insecticide, wetting agent, plasticizer, detergent, rubber-vulcanizing agent, or other valuable product."

Each has to be named and recorded systematically, and some that are especially complex need long descriptive names, which to a trained chemist really picture the compound.



Shucks! I lost track of what I was doing!"

Chemical Things To Do:

Watch Smoke Particles Dance

by JOSEPH H. KRAUS

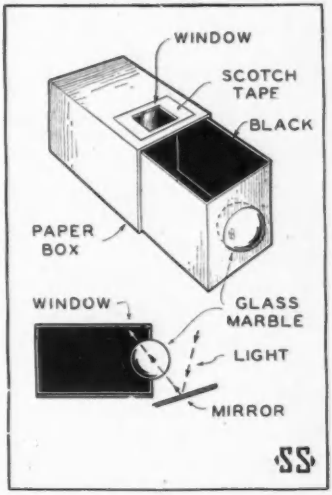
▸SCIENTISTS TODAY are changing the structure of molecules and by such changes are developing all sorts of synthetic products which were never known before. Yet an ordinary microscope is not powerful enough to show what a molecule looks like. Scientists cannot see the changes they create.

Junior scientists, however, can show that molecules constantly are bumping into each other and rebounding again. This is done not by actually seeing them strike, but by looking at some solid substance small enough and light enough in weight to be moved when bombarded by the molecules. Smoke is one such substance.

A demonstration can be arranged by building the equipment illustrated in the accompanying diagram. A small box like a safety match box or pill box is needed. A small lens from a flashlight or a reasonably clear marble will serve to focus light into the box. A piece of glass becomes the window.

Paint the inside of the box black with India ink or apply several coats of ordinary ink. Cut a hole in the end of the box almost large enough to hold the glass marble, then force the marble into the opening.

Cut a hole in the shell of the box and cover with a piece of clear glass. Arrange a handbag mirror in such a position that a strong beam of light is projected at the marble, preferably somewhat from below, as shown. A flashlight, with the beam focused at



the marble through a mailing tube to keep the light from scattering, can also be used. A shielded 110-volt lamp will give a brighter light.

Blow Smoke Into Box

Ask someone to blow cigarette smoke into the open box and close it quickly. Now place the box so that the light will fall on the marble.

The smoke particles in the beam of light within the box will be illuminated brightly. Let them come to rest somewhat. If observed with a low-power microscope such as is found in high school and home laboratories, the smoke particles can be seen to move in an erratic manner. Instead of

going all in one direction as when blown by air, they dart back and forth for short distances. All the smoke particles, which look like twinkling stars, take part in the movement. Be sure that you see the individual particles of smoke, not a cloud, when you look through the microscope. You can see them better if the room is kept dark.

Scientists hold that this movement is the result of a bombardment of the smoke particles by the molecules of air. When more molecules strike the smoke particles on one side than on the other, the motion takes place.

This motion is known as the Brownian movement and was first observed in 1827. In 1905 Professor Einstein showed that the character of the movement can be predicted accurately.

Just in case you would like to know: in round numbers and under normal conditions, there are about 443,300,000,000,000,000,000 molecules of gas in one cubic inch of space. This figure is a constant for all gases. But no one knows how many of these quintillions of molecules must bump into the smoke particles to give it one of the erratic movements seen in the experiment.

Cut Industrial Diamonds With Electric Arc

➤ CUTTING industrial diamonds with an electric arc, a new process just developed at the National Bureau of Standards, increases the rate of cutting from double to four times that of present methods. The discovery is perhaps the greatest real advance in the technique of cutting diamonds since the art was first practiced hundreds of years ago.

Two scientists of the Bureau are responsible for the new method, C. G. Peters and Karl F. Nefflen. They find that they are able, with the electric arc method, to double the cutting rate when the cut is in the most favorable direction as regards the crystal axis, and to increase the rate about four times for the least favorable direction.

The electric arc is formed between the diamond and the cutting lap. Messrs. Peters and Nefflen connect the secondary terminals of a 5000-volt power transformer to the dop that holds the diamond and to the rotating lap. When an alternating current of 110 volts is applied to the primary of the transformer and the current adjusted to about half an ampere, a small blue arc is formed at the contact of the diamond and lap.

They have also found that by applying the arc to a diamond saw, the sawing rate is greatly increased, so that diamonds can be sawed regardless of the orientation of the cut with reference to the crystal axes.

The method for cutting plane surfaces or facets on diamonds, used universally since the earliest records, has been to place the stone in contact with a flat cast-iron lap charged with diamond powder and rotated at about 2000 revolutions per minute. As a general rule, cutting is most rapid when the plane of the facet is parallel to one or two of the crystal axes of the diamond and the direction of motion of the lap surface is parallel to one of the axes. For other positions, the cutting rate decreases rapidly.

Recent U. S. Patents Cover Wide Chemical Fields

Chemistry in New Patents

Patents constitute one of the most important ways that new advances in chemistry are made known to the world. This department that appears each month in CHEMISTRY *picks the highlights among the several thousand patents issued each month. Anyone may obtain a copy of a patent by ordering by number from the U. S. Patent Office, Washington, D. C., and remitting 10 cents in money order, cash or Patent Office coupon.*

Avocado Oil Extraction

▶ LARGER SUPPLIES of a highly desirable food oil may result from a new and simple method of chemical extraction on which patent 2,383,398 has been granted to Howard T. Love, chemist at the Insular Experiment Station at Mayaguez, P. R. Patent rights are dedicated "to the free use of the people of the Territory of the United States."

Avocado pulp contains considerable quantities of high-grade edible oil; it is the only widely-cultivated fruit that is high in oil. At present, avocado oil extraction must begin by dehydrating the pulp—a relatively costly and difficult process, that may easily ruin the oil by overheating. Mr. Love gets the oil out of the plant cells without first removing the water by treating the mashed pulp with oxide of lime or one of a number of alkalis and halogen salts. Then the oil is separated out by pressing or centrifuging. Yellow or green oil may be obtained at will by regulating the length of the initial chemical treatment.

Solar Water Still

▶ PERSONS whose jobs require them to live in desert regions where the only available water is alkali or salt are offered a way to distil fresh water out of it with no fuel other than sunlight, in the invention on which patent 2,383,234 has been granted to W. S. Barnes of Tucson, Ariz.

The unpotable water is held in a long tank, preferably oriented with its long axis on an east-west line. This is covered with a gabled glass roof, or a saw-tooth series of such roofs, with a sprinkler-pipe running along the ridgepole. Daytime heat evaporates part of the water, and cooling sprays over the outside of the glass condense the vapor on the inside, where it trickles down into appropriately placed troughs and pipelines. Incidentally, the glass roof is hopefully provided with gutters and spouts, to catch such occasional rains as do fall in almost all deserts.

Night Shining Pigments

▶ DOORKNOBS, light-switches and other things necessary but difficult to find in the dark are sometimes made luminescent by coating on or incorporating in them night-shining pigments. A new effort to make more satisfactory articles of this class is represented in patent 2,383,067, obtained by two du Pont chemists, M. L. Macht of Jersey City and M. M. Renfrew of Arlington, N. J., who have assigned rights to their employing firm. They mix the luminescent pigment particles into a methyl methacrylate matrix that

is soft enough to be moldable but viscid enough to prevent the particles from settling out before it hardens.

Cleaner Glass

➤ MORE PERFECT mirrors and other articles of metal-coated glass are in prospect as a result of a method covered by patent 2,383,469, issued to W. H. Colbert and A. R. Weinrich of Brackenridge, Pa., assignors to Libbey-Owens-Ford Glass Company of Toledo, Ohio.

Imperfections in metal coatings on glass, the inventors explain, are almost always due to invisibly thin layers of dirt, especially grease. To get a really clean surface, they first wash their glass thoroughly, then coat it with a heavy oil or other liquid with high evaporating point. This coating is wiped off, leaving only an invisibly thin layer of the oil.

The glass is then placed in a closed vessel, where it is subjected to a rather high vacuum and at the same time bombarded with an electrical glow discharge. This gives as nearly a perfectly clean surface as is practically attainable. Left in the vacuum chamber, the glass may then be immediately coated with a reflecting metal by the vapor process.

A somewhat similar process, but adapted for the mass production of decorated table glass and similar articles, is covered by patent 2,383,470, issued to W. L. Morgan of Columbus, Ohio, and also assigned to the Libbey-Owens-Ford Company.

Magnesium From Scrap

➤ A METHOD for recovering magnesium from turnings, borings and other scrap in which it is mixed with other metals is the subject of patent 2,383,659, obtained by Y. E. Lebedeff of Metuchen, N. J., who has assigned his rights to the American Smelting and Refining Company. First a molten bath of a collector metal, like lead or zinc, is prepared. This is covered by a slag composed of a mixture of lead chloride or the like, mixed with common salt. The bath is heated to about 900 degrees Fahrenheit, and stirred vigorously, while the magnesium scrap is poured in. After about an hour of stirring, the slag will have collected practically all the impurities and can be skimmed off, leaving the magnesium behind.

Vitamin C From Fruit

➤ CHEMICAL spoils of war are represented in patent 2,383,902, which is on a method for extracting vitamin C from pineapple and other fruit juices by treatment with calcium carbonate and the oxides of magnesium and calcium. The patent was applied for in 1939 by Ryo Yamamoto and Takeshi Hara of Taiwan (Formosa); it is of course vested in the Alien Property Custodian, and may be licensed by any American who wants to use the method.

Scent Fixative

➤ LEAVES of a shrub commonly called sweet fern (though it is not a fern but a flowering plant) are used in preparing a new fixative for scents in perfumes, under patent 2,383,517, taken out by a Swiss chemist, Maurice Sandoz of Vevey La Tour, and assigned to Burton T. Bush, Inc., of New York. Botanically the plant is known as Comptonia asplenifolia; it grows wild in dry, sterile soil in the eastern part of this country.

Brighter Tinplate

➤ BETTER and brighter tinplate, for cans, bottle caps and a thousand other uses, is promised by a new process on which U. S. patent 2,384,086 has just been issued, to Charles E. Glock of Baltimore. The tin is deposited on the steel or black-iron sheet as the latter is passed vertically through an electrolytic bath in a continuous strip. After being coated, the sheet is cold-rolled at very high pressure—250,000 to 500,000 pounds are the figures given by the inventor—at speeds up to 2,000 feet a minute. The metal is slightly elongated during the rolling, increase in length being on the order of $\frac{3}{4}$ inch for every 25 inches.

Because the plate is at no time brought into contact with oil, its surface is kept in good condition to take printing or lithographing, often used on can labels and bottle caps. During the process a film of water is maintained on the surface, to protect it against oygen in the air and prevent incipient rusting. Mr. Glock has assigned his patent rights to the Crown Cork and Seal Company.

Magnetic Powder Metallurgy

➤ A NEW DEPARTURE in powder metallurgy is the subject of patent 2,384,215, granted to Harry A. Toulmin, Jr., of Oakwood, Ohio. It involves the use of a strong magnetic field, created by an electromagnet around the mold, to arrange the metallic particles in a compact and orderly system. Then supersonic vibrations are applied, further to compact them, after which the mass is placed under pressure to solidify it. The inventor states that with his system it is not necessary to use final sintering, that is, to heat the mass until the particles fuse together; though heating may be added to the process if desired. Patent rights are assigned to the H-P-M Development Corporation, of Wilmington, Del.

De-Kinking Wool

➤ LAMBSKIN coats with smooth and silky hair, very much in fashion nowadays, of course need to have the wool de-kinked before they can be made up. Use of chlorine or a related chemical element to accomplish this is the basis of patent 2,383,963, issued to the estate of the late S. S. Gottfried of New York. The skins are first treated with a solution of sulfuric acid and common salt, then with a bath containing calcium chloride and chlorine dissolved in water, which takes the curl out of the hair. A neutralizing bath of sodium thiosulfate solution removes the chlorine. The treatment is said to make the hairs water-repellent as well as smooth.

Shipping Caustics

➤ SHIPMENT of caustic soda and caustic potash in metal drums or tank cars is made safer and more satisfactory by a simple process whereby they are given rubber-film linings, covered by patent 2,384,111, which was obtained by Dwight Means of Wadsworth, Ohio, assignor to the Pittsburgh Plate Glass Company.

It is customary to fill containers with the caustics in molten form, and to heat them again when preparing to empty them. In their heated state the caustics are highly corrosive, which not only increases risks in handling them but introduces iron from the container as an impurity in the chemical. Mr. Means remedies this by coating the inner surface of the container with rubber latex in which sulfur and

other vulcanizing materials are already incorporated. When the hot caustic is poured in, the heat suffices to vulcanize the rubber into a firm, impermeable protective surface.

Cleaning Powder

➤ A COMBINED scouring and polishing powder, covered by patent 2,384,006, is the invention of Joseph M. Bleakney of Manhasset, N. Y. It incorporates sawdust, to make it lighter and less scratchy in its action; other ingredients are diatomaceous earth, soap powder and a binder.

New Synthetic Rubbers

➤ TWO RESEARCH chemists of the B. F. Goodrich Company at Akron, Dr. Waldo L. Semon and Dr. Charles F. Fryling, have just received a number of U. S. patents on new synthetic rubbers. Although many possible compounds are listed, they all call for butadiene or one of its close chemical relatives as a principal ingredient. Instead of the styrene which forms the other half of the present standard GR-S rubber, these new synthetics call for acrylonitrile and one other ingredient, which may be selected from a considerable list, but usually belongs to the group known as the alkyl acrylates.

Among the advantages claimed for the new synthetics are high plasticity and easy workability in the unvulcanized state, with great strength and elasticity after vulcanization. They are said to be especially good at low temperatures, such as are encountered by aircraft at high altitudes. Each of the two chemists received five patents; Dr. Semon's are numbered 2,384,568 to 2,384,572, and Dr. Fryling's from 2,384,543 to 2,384,547. Rights in all are assigned to the B. F. Goodrich Company.

Water-Glass Insulator

➤ THREE CHEMISTS employed by the Chicago plant of Western Electric Company, Dr. H. F. Fruth, Dr. W. O. Haas, Jr., and Dr. E. G. Walters, have assigned to that firm their rights in patent 2,384,542, on a method for insulating electric wires with sodium silicate, long familiar as a cheap adhesive and as a preservative for eggs. This compound is known to be a good insulator, but it has suffered from a double drawback. If applied to the wire in melted condition it becomes too brittle on hardening; if put on in a water solution it tends to take up water out of the atmosphere after it has dried. The three chemists have found that if the silicate is applied in solution and the coated wire then heated, the silicate remains as a good and flexible insulation, but is not hygroscopic. Best results are obtained with a sodium silicate in which the ratio of silicon to soda is relatively high.

Indium Recovery

➤ INDIUM, a scarce metal related to aluminum, used in small quantities as an alloy in dental work and as a plating material, is recovered from zinc, in which it occurs as an impurity, by a chemical method on which patent 2,384,610 was granted to H. M. Doran, M. A. Jackson and A. I. Alf, all of Great Falls, Mont. Essential steps are solution in sulfuric acid, with subsequent electrolytic recovery of the zinc, and precipitation of the indium in the form of a bisulfite. The latter salt is further treated to free it from iron, aluminum and other impurities, then redissolved in an acid and subjected to electrolysis to get out the pure metallic indium.

Chem Quiz:

What is the State of These Elements?

TOWNS of the U. S. A. have taken their names from many circumstances. Chemists may be surprised to learn that a goodly number of town names are connected with their profession. We have selected a few names of elements. Their chemical states are solid, liquid and gas. Can you name the state (or territory) of the U. S. A. which contains each of these elements —as a town? If not you may address your inquiries to page 50.

Antimony
Calcium
Cobalt
Krypton
Lithium
Mercury
Neon
Platinum
Vanadium
Zinc

Sodium Silicate Bounces Like Rubber

CONCENTRATED sodium silicate solutions show the same physical properties as "bouncing putty," a by-product of the research that developed silicone rubber, D. L. Hanna of the Illinois State Geological Survey reports. Sodium silicate, commonly sold under the name of water-glass, is widely used in thin solutions as an adhesive and for the preservation of eggs.

The "bounceability" of concentrated sodium silicate was discovered by chance in an overlooked laboratory solution, that had slowly dried to about 54% water content.

The concentrated material was a transparent rubbery liquid. When shaped into a ball it was bounced off a hard surface like so much rubber. It was not sticky and could be bounced off a surface of the same material. It retains its ability to bounce indefinitely if prevented from losing additional water. If unprotected and left in the air, it dries out rapidly and becomes brittle.

Bouncing putty, which looks and feels like ordinary putty, was discovered in research work in developing silicone rubber. It can be pulled and kneaded like putty, and when made into a ball and dropped on the floor bounces like rubber.

Silicone rubber is a relatively new type of synthetic rubber in which silicon replaces carbon. It belongs to the new chemical family of silicones. It possesses important advantages over synthetic and natural rubber in several ways. It withstands relatively high and low temperatures and the action of ultraviolet rays. It has many possible postwar uses.

Chemical Aspects of Man's Fight Against Disease

Advances In Medicine

Recent progress in medicines are reported by Jane Stafford, Science Service medical writer, in this article.

Streptomycin for Tuberculosis

➤ STREPTOMYCIN, penicillin-like medical weapon which proved strikingly effective in controlling tuberculosis in guinea pigs, has been given to 34 human patients suffering from this disease.

The results of this first trial of the remedy in human tuberculosis are reported by Dr. H. C. Hinshaw and Dr. W. H. Feldman, of the Mayo Clinic and Foundation in the Proceedings of the Staff Meetings of the Mayo Clinic.

A "limited suppressive effect" on the disease, especially in some of the more unusual types of tuberculosis, was obtained through streptomycin treatment.

Many of the cases in which streptomycin was tried were apparently hopeless. In these the drug brought about some improvement and perhaps prolonged the lives of the patients. Yet nowhere in the report is there any statement to justify hailing this new drug as a swift and sure cure for tuberculosis.

An unusual feature of the report is the inclusion of a paragraph indirectly addressed to lay persons. In this the scientists, who obviously restrained their report to the most conservative statements, urge the layman who may hear of it to adopt "the same cautious frame of mind." In other words, not too much hope should be aroused by the results so far.

"No one as yet knows what the final judgment will be concerning the effect of streptomycin on clinical tuberculosis," they state.

Care in a sanatorium and collapse therapy, proved and effective methods of treating tuberculosis, should "in no instance" be abandoned for treatment with streptomycin or other antibacterial substances whose value has not yet been conclusively shown.

Very much in favor of streptomycin is its safety, as shown by study of the 34 patients to whom it was given by injection into the muscles every three hours and in some cases for several weeks without interruption. Most patients complained of feeling a little sick and of aching muscles and pain where the injections were made. The pain is no worse than that produced by penicillin. Since most of the patients to whom streptomycin was given had little chance for rapid recovery, if any, they did not mind the discomfort of the new treatment that might help them. As more purified lots of streptomycin have become available, there have been less severe reactions to it.

Streptomycin seems to have the best effect in patients with unusual and particularly dangerous forms of tuberculosis, such as tuberculosis of kidneys and bladder and the type known medically as miliary tuberculosis. In miliary tuberculosis the disease is not limited to the lungs but is spread through the

body by the blood stream and usually is rapidly fatal.

In two patients with this form of tuberculosis, one of whom also had tuberculosis of the kidneys, "unmistakable and striking improvement" of the tuberculous condition of the lungs appeared in X-ray pictures. Improvement in the general condition of the patients, however, did not parallel that shown in the chest X-rays, and the physicians believe the disease has become localized in some inaccessible regions of the body.

Encouraging results were obtained when streptomycin was given to four patients with tuberculosis of the bladder or kidneys. Each of these had only one kidney, the other having been removed because of the tuberculous condition. Each was excreting tuberculosis germs before streptomycin treatment was started. This stopped within two to four weeks and no germs have been found up to four months after the drug was stopped.

Some of the patients with tuberculosis of the lungs, on the other hand, although they seem to respond to streptomycin, apparently are better only so long as they are taking the drug. In some cases the tuberculous process is reactivated promptly after treatment is stopped. Extensive, progressive lung damage known to be of recent origin tended to improve promptly in a manner resembling the natural processes of healing. The drug, however, did not seem to have any rapidly effective curative action in these cases.

These results lead the scientists to believe that streptomycin checks the growth of the tuberculosis germs, thus suppressing the symptoms of the disease, but that it does not actually kill the germs and in that sense cure the disease.

A few patients with tuberculosis of the skin were given streptomycin. Not enough time has elapsed to be sure of the permanency of the results in these patients, but in three of them inflamed lymph glands that were discharging pus cleared up promptly.

Streptomycin, obtained from a mold-like germ that lives in the soil, was discovered by Dr. Selman A. Waksman and associates of Rutgers University and the New Jersey Agricultural Experiment Station. His finding that the germ-chemical was a powerful weapon against tuberculosis germs in the test tube led to its trials by the Mayo scientists.

When it showed itself much less toxic and more powerful than any of the sufone drugs previously used in treatment of experimental tuberculosis of guinea pigs, trials on human patients were started. In these Drs. Feldman and Hinshaw had the assistance of Dr. Karl Pfuetze, of Mineral Springs Sanatorium, and of colleagues at the Mayo Clinic, including Drs. Herman Moersch, Arthur Olsen, Harry Wood, Wallace Herrell, Fordyce Heilman, Dorothy Heilman, Robert Glover, R. L. J. Kennedy, L. F. Greene, W. G. Braasch, E. N. Cook, P. A. O'Leary, E. T. Ceder, L. A. Brunsting and F. A. Figi.

Disinfection of Schoolroom Air

➤ THE EVER-DIFFICULT problem of hygienic school room ventilation may be solved by ultraviolet light, it appears from a report of Dr. Mildred Weeks Wells, of the University of Pennsylvania School of Medicine, in a recent issue of the Journal of the American Medical Association.

"School ventilation, which has necessarily been curtailed on account of fuel shortages during the war, will probably never return to prewar standards," she declares. "Enlightened opinion, which formerly opposed, on hygienic grounds, lowering the volume of air change, now recognizes the potentiality of higher standards of sanitary ventilation through air disinfection, which can practicably provide the hygienic equivalent of ventilation impossible of attainment by actual air replacement."

The school ventilation standard of 30 cubic feet of air per minute per child is not only difficult to attain; it is not enough to prevent classroom spread of chickenpox and measles except in rooms where less than 40% of the pupils are susceptible to chickenpox and less than 20% are susceptible to measles.

In contrast to this, Dr. Wells found the chances of a susceptible child getting measles, chickenpox or mumps from a classmate can be definitely reduced by disinfecting schoolroom air with ultraviolet light.

Her conclusions are based on studies begun in the Germantown, Pa., Friends School in 1937 and subsequently expanded so that since the fall of 1941 they have included two neighboring private schools and two groups of public schools in Philadelphia suburbs.

Even better results may be attained with air disinfection as the result of the early experience with it. Proper servicing of the lamps is important. Teachers and pupils should understand how they work so as to avoid the mistake made in one school of draping the lights with autumn leaves and Spanish moss for the Thanksgiving festivities. This, of course, blocks the ultraviolet rays so they cannot get at the germs in the air to kill them.

In a first grade outbreak of measles, nine little girls being infected from a classmate, the cause was apparently the fact that a playhouse was put into the schoolroom. This reproduced in miniature the exact situation the lights were designed to prevent. It gave a chance for germ-laden droplets of moisture from one little girl's breath to reach all the others without having been exposed to the germ-killing light.

When the air has a high relative humidity, as it may in fall before the heat is on, the ultraviolet light is less effective in killing germs. This difficulty may be unavoidable.

Gramicidin Improved

➤ GRAMACIDIN, one of the first of the germ-stopping antibiotics to be discovered, has never come into use for disease treatment because it is poisonous to animal tissues, and also destructive to red blood corpuscles. Addition of formaldehyde to gramicidin solutions renders it less harmful in these respects, while its ability to check the growth of bacteria remains unchanged. Dr. J. C. Lewis and a group of five colleagues report in a recent issue of *Science*.

Dr. Lewis and his research team carried on their work at the Western Regional Research Laboratory of the U. S. Department of Agriculture at Albany, Calif. They are continuing their investigations, and promise a fuller report at a future date.

Unlike penicillin, which is derived from a mold, gramicidin is produced by a soil-dwelling bacterium.

No Longer Japanese Monopoly . Synthetic Camphor Finds Many Uses

From Medicines to Movies

Sixth of a Series on Basic and War Chemicals

by Dr. C. M. A. Stine
Vice-President Advisory on Research and Development, E. I. du Pont de Nemours & Co.

Southern pine trees and the skill of American chemists are supplying the United States with a versatile product in which Japan once held a tight monopoly.

This is camphor, an important ingredient of thousands of peace-time and war-time products, from liniments, unguents, stimulants and other pharmaceuticals to scuffless plastic heel covering on women's shoes, movie films, military drafting instruments and motorcycle windshields.

Stately camphor trees of the Orient have for thousands of years been giving off their fresh and heady odor—an odor that carries for miles. Many centuries ago the natives learned to distill the camphor wood, using crude bamboo tubes to condense the snow-white crystals. These they pressed into small amulets to insure health and to serve as symbols of pagan belief. It is said that the Arabian physicians of the 11th Century appreciated the medicinal value of camphor.

One of the richest sources of this prized substance was the Island of Formosa. The Chinese came to this island off their southeast coast in 1421 and occupied it until the Japs took over in 1895. By this time the cellulose plastic industry was under way. It used large amounts of camphor as a plasticizer in transforming chemically-treated cotton into combs, umbrella handles, toys and celluloid collars, with the result that the camphor trees began to fall thick and fast until the only remaining ones were in Formosa, where the Japs had practiced conservation. This enabled the Japanese to hold a monopoly on camphor and they ran the price up to $3.75 per pound by the end of the First World War, and even in 1920 it reached $3.65 a pound.

Meanwhile the chemists had learned the structural formula of camphor and had found out how to make it from pinene, the essence of turpentine. German, Swiss and Italian plants were turning synthetic camphor out early in the 20th Century and a start was made in this country in 1900. Several other efforts were also made during the first third of the 20th Century but large-scale operations did not begin until the Du Pont Company opened its camphor plant in 1932. Turning out more than 7,000,000 pounds of camphor a year this plant now produces most of the camphor manufactured in this country. That for medicinal uses sells at about 70 cents per pound, and the commercial grade used in plastics sells for less than 50 cents.

Pinene, the starting material for camphor production, is a clear, watery fluid which looks and smells much like turpentine. In fact, turpentine is 95 per cent pinene, which is distilled

off, usually near the pine forests yielding the turpentine and shipped to the camphor plant in tank cars.

Looking at their chemical formulas, $C_{10}H_{16}$ for pinene and $C_{10}H_{16}O$ for camphor, one might conclude that all the chemist had to do to make camphor is to tack an atom of oxygen onto the cluster of ten carbon atoms and 16 hydrogen atoms that make up pinene. Actually the architecture of the two molecules differs more than the simple statement of their atomic ingredients indicates. Therefore the pinene must go through several stages of chemical treatment, heating, cooling and distillation, in order to put the needed oxygen atom in at the proper place. One of the by-products of this process is terpene-B-hydrocarbon, which is now in great demand as a solvent for reclaiming rubber.

In the last step the hot, molten camphor flows onto a brine-chilled drum, where it solidifies and from which it is immediately scraped off as snow-white flakes. These are poured into paper-lined wooden barrels for shipment to the various plastics and film manufacturers.

Large quantities of camphor were used during the war in making the photographic film used by our Army and Navy. Hundreds of thousands of pounds of it are used each year in the films supplied to the movie industry. Heavier transparent films are used as windshields on motorcycles and certain types of airplanes, and also as map containers and covers for use in the field. Thinner sheets go into identification tags and buttons for workers, gauge covers and scores of other items. Among the countless other articles made of camphor-containing plastics, broadly designated as pyroxylin, are shoe-lace tips—substituting for tin in this item—fountain pens and pencils, drafting instruments, eyeglass frames, slide rules, sound-damping materials in radio sets.

There is one small physical difference between natural and synthetic camphor. The natural product is "right-handed" and the synthetic is what might be called "ambidextrous," that is, a mixture of rights and lefts. This curious distinction is known as optical isomerism and is based on the fact that certain chemicals occur in two crystalline forms, which are the mirror images of each other, just as your right hand is a mirror-image of your left. A solution of one form of crystals bends or rotates polarized light to the right, and is called dextro-rotatory. The other form rotates it to the left, and is called laevo-rotatory. A mixture of equal amounts of left-handed and right-handed crystals doesn't rotate the light at all. Synthetic camphor is such a mixture of the two forms. Incidentally, the pinene from American turpentine is right-handed, that from French turpentine is left-handed. But right or left, or mixed, the camphor derived from turpentine is chemically identical with that from the camphor tree, and is doing an important job in American industry.

Shot for shotguns is made today much as for years; melted mixed lead and antimony passes through round holes in the bottom of a pan at the top of a seven-story shaft, falling into water at the bottom and forming spheres as they fall.

A Modern Metal, an Ancient One and The First Added to the Alchemists' List

Zinc, Cadmium and Mercury

A Classic of Chemistry

MERCURY was known to the Egyptians, and its discovery probably antedates even their early writings. Theophrastus was a Greek writer who described stones "for use and for amusement." Here he describes the ore, natural cinnabar, and artificial cinnabar, which he says was a new discovery in his time. Zinc was discovered some time in the Dark Ages. Cadmium is the modern member of Group II b.

Zinc

THE HERMETIC AND ALCHEMICAL WRITINGS OF AUREOLUS PHILIPPUS THEOPHRASTUS BOMBAST, OF HOHENHEIM, CALLED PARACELSUS THE GREAT. Now for the first time faithfully translated into English. By Arthur Edward Waite. In two volumes, Vol. I. London: 1894.

SUCH AND SO many in number are the metals, as I have reckoned them up, namely gold, silver, tin, lead, iron, steel, female copper, and male copper. Thus they are eight in number. But if—as cannot be the case—iron and steel, and male and female copper respectively, are reckoned each as one metal, there would be only six, and the arrangement would be inconvenient. There are seven well-defined and publicly known metals: gold, silver, tin, lead, iron, steel, and copper, the last being reckoned as one metal, since

Paracelsus

the male and female are wrought together and not separated, as they ought to be.

Of Mixed Metals:

You perceive, from what has been already said, that the male is not always solitary without a consort, but often they co-exist, as in the cases of gold and silver, iron and steel, which grow together in one working, from which each retains it own special nature, but still they are mixed so that one does not impede the other, nor are they of their own accord separated one from the other. Such, too, is often the case with tin and lead. But where they are thus joined no good results ensues from them. They do not square

into one body; but it is better that each should be separated into its own body.

Concerning Spurious Metals:

Metals can be adulterated. Only gold and silver mix with the other metals, for the reason that they are the most subtle. Only, therefore, when such a primal matter is present, does each grow up together by itself. It may easily be that six or seven different fruits shall be grafted together on the same tree; and there is the same marvellous kind of implantation here in Nature.

Concerning Zinc:

Moreover, there is a certain metal, not commonly known, called zinc. It is of peculiar nature and origin. Many metals are adulterated in it. The metal of itself is fluid, because it is generated from three fluid primals. It does not admit of hammering, only of fusion. Its colours are different from other colours, so that it resembles no other metals in the condition of growth. Such, I say, is this metal that its ultimate matter, to me at least, is not yet fully known. It does not admit of admixture; nor does it allow the fabrications of other metals. It stands alone by itself.

Concerning Quicksilver:

There is, moreover, a certain genus which is neither hammered nor founded; and it is a mineral water of metals. As water is to other substances, so is this with reference to metals. So far it should be a metal as Alchemy reduces it to malleability and capacity of being wrought. Commonly it has no consistence, but sometimes it has. The right opinion about it is that it is the primal matter of the Alchemists, who know how to get from it silver, gold, copper, etc., as the event proves. Possibly also tin, lead, and iron can be made from it. Its nature is manifold and marvellous, and can only be studied with great toil and constant application. This, at all events, is clear, that it is the primal matter of the Alchemists in generating metals, and, moreover, a remarkable medicine. It is produced from Sulphur, Mercury, and Salt, with this remarkable nature that it is a fluid but does not moisten, and runs about, though it has no feet. It is the heaviest of all the metals.

Cadmium

NEW DETAILS RESPECTING CADMIUM. By M. Stromeyer. In Annals of Philosophy; Vol. XIV, October, 1819 (From Annalen der Physik, lx, 193).

➤ M. STROMEYER has communicated to the Royal Society of Göttingen, at the meeting of Sept. 10, 1818, the first part of his researches on the new metal which he discovered in zinc and its oxides, and to which he has given the name of *cadmium*. Assisted by two of his pupils, M. Mahner, of Brunswick, and M. Siemens, of Hamburgh, he has not only verified his first results, but has been able to give greater extent to his researches, and to reduce them to a great degree of precision. He states that he has explained more fully the circumstances which led to the discovery of cadmium; and in that way has shown the part which M. Hermann of Schoenbeck, and Dr. Roloff, of Magdeburg, had in it. He gives likewise the names of the different species of zinc,

Friedrich Stromeyer

of its oxides, or of its ores, which contain cadmium. Among these last, M. Stromeyer has found it only in a very small proportion in some blends with the exception of some varieties of radiated blende of Przibram, in Hungary, which contains two or three per cent of it. He likewise gives the process for procuring cadmium in a state of purity.

According to this process, we begin by dissolving in sulphuric acid the substances which contain cadmium, and through the solution, which must contain a sufficient excess of acid, a current of sulphuretted hydrogen gas must be passed. The precipitate formed is collected and well washed. It is then dissolved in concentrated muriatic acid, and the excess of acid driven off by evaporation. The residue is dissolved in water, and precipitated by carbonate of ammonia, of which an excess is added to redissolve the zinc and the copper that may have been precipitated by the sulphuretted hydrogen gas. The carbonate of cadmium, being well washed, is heated to drive off the carbonic acid, and the remaining oxide is reduced by mixing it with lamp-black, and exposing it to a moderate red heat in a glass, or earthen retort.

The colour of cadmium is a fine white, with a slight shade of bluish-grey, and approaching much to that of tin. Like this last metal, it has a strong lustre, and takes a good polish. Its texture is perfectly compact, and its fracture hackly. It crystallizes easily in octahedrons, and presents at its surface on cooling the appearance of leaves of fern. It is soft, very flexible, and yields readily to the file, or the knife. It stains pretty strongly; however, it is harder than tin, and surpasses it in tenacity. It is likewise very ductile, and may be reduced to fine wires, or thin plates; yet, when long hammered, it scales off in different places. Its specific gravity, without being hammered, is 8.6040, at the temperature of 62°; when hammered, it is 8.6944. It melts before being heated to redness, and is volatilized at a heat not much greater than what is necessary to volatilize mercury. Its vapour has no peculiar odour. It condenses in drops as readily as mercury, which, on congealing, present distinct traces of crystallization.

Cadmium is as little altered by exposure to the air as tin. When heated in the open air, it burns as readily as this last metal, and is converted into a brownish-yellow oxide, which appears usually under the form of a smoke of

the same colour; but which is very fixed. Nitric acid dissolves it easily cold; diluted sulphuric acid, muriatic acid, and even acetic acid, attack it with disengagement of hydrogen gas; but their action is very feeble, especially that of acetic acid, even when it is assisted by heat. The solutions are colourless, and are not precipitated by water.

Mercury

THEOPHRASTUS'S HISTORY OF STONES. With an English Version and Notes. By Sir John Hill, London: M DCC LXXIV (1774).

➤ THERE ARE also two kinds of Cinnabar, the one native, the other factitious; the native, which is found in *Spain,* is hard and stony; as is also that brought from *Colchis,* which they say is produced there in Rocks and on Precipices, from which they get it down with Darts and Arrows. The factitious is from the Country a little above *Ephesus;* it is but in small Quantities, and is had only from one Place. It is only a Sand, shining like Scarlet, which they collect, and rub to a very fine Powder, in Vessels of Stone only; and afterwards wash in other Vessels of Brass, or sometimes of Wood. What subsides they go to work on again, rubbing it and washing it as before. And in this Work there is much Art to be used; for from an equal Quantity of the Sand some will make a large Quantity of the Powder, and others very little, or none at all. The Washing they use is very light and superficial, and they wet it every time separately and carefully. That which at last subsides is the Cinnabar, and that which swims above in much larger Quantity is only the superfluous Matter of the Washing.

It is said, that one *Callias, an Athenian,* who belonged to the Silver Mines, invented and taught the making of this artificial Cinnabar. He had carefully got together a great Quantity of this Sand, imagining, from its shining Appearance, that it contained Gold: But when he had found that it did not, and had had an Opportunity, in his Trials, of admiring the Beauty of its Colour, he invented and brought into use this Preparation of it. And this is no old Thing, the Invention being only of about ninety Years Date; *Praxibulus* being at this Time in the Government of *Athens.*

From these Accounts it is manifest, that Art imitates Nature, and sometimes produces very peculiar Things; some of which are for Use, others for Amusement only, as those employed in the ornamenting Edifices; and others, both for Amusement and Use. Such is the Production of Quicksilver, which has its Uses: This is obtained from native Cinnabar, rubbed with Vinegar in a brass Mortar with a brass Pestle. And many other Things of this kind others, perhaps, may hit upon.

The total amount of iodine found in the average man weighs a little less than a drop of water; about one-half of this essential material is located in the thyroid gland and the rest distributed to every cell in the body.

Who's Who in This Month's Classic

➤ PARACELSUS, as he called himself, or THEOPHRASTUS BOMBASTUS VON HOHENHEIM (*c.* 1490-1541), was one of the odd characters that turn up on the "lunatic fringe" of a new science. Perhaps we should not expect too much of a man of his time. Part of his schooling was under a master who was seeking the Great Elixir. Young Theophrastus finally gave up studies and worked in the mines of the Tyrol, where he found real knowledge of chemistry. Since his father was a physician and his mother, before her marriage, the superintendent of a hospital, Theophrastus seems to have drifted naturally into the practice of medicine. He tried out his chemicals on sick miners, and often cured them. When he was made town physician of Basel, about 1526, he incurred the wrath of the old-school physicians by lecturing in German instead of Latin, by recommending procedures not laid down by Galen, and by accusing the influential of hypocrisy and greed. It was at this point that he adopted his new name, by which he advertised himself as "better than Celsus." The powers-that-be retaliated by turning his surname Bombast into an epithet. The pattern of the controvery is a familiar and recurring one. It is impossible after so long a time to tell which side was most in the wrong.

➤ THEOPHRASTUS, the Greek, (371-288 B.C.) was "on the Faculty" of Aristotle's Lyceum, and succeeded the founder in 323 when political danger following the death of Alexander made it expedient for Aristotle to retire. A year later Theophrastus was one of the executors of the will of the great philosopher.

➤ FRIEDRICH STROMEYER (1776-1835) was born and died at Göttingen, and spent his life teaching at its famous university. His career followed the inevitable pattern of the 19th century German professor. He received his Doctor's degree in 1800, became Privatdoctent in 1802, Professor Extraordinary in 1805, Ordinary in 1810, headed the department of Chemistry and Pharmacy from 1817 on, and raised a son, Dr. Edouard Christian Friedrich Stromeyer, who took his Doctor's degree at Göttingen in 1831 and carried on the profession. Mineral analysis was the special field of Stromeyer, Senior, and in the course of it he happened upon the metal cadmium, not previously distinguished from the accompanying zinc.

Standards for Asbestos Protective Clothing

➤ ASBESTOS aprons, cape sleeves and bibs, leggings and coats, fabricated according to new American War Standards specifications formulated, will give increased protection from injury from sudden splashes or spills of molten metals to workers in steel mills and foundries. They are issued by the American Standards Association, and are intended to assure a quality of asbestos protective clothing that will scorch slowly enough to give wearers time to get out of danger and remove the garments.

Helium Gas Usable in Tires

➤ HELIUM, the exclusively American balloon gas, can be used economically to inflate the huge tires of passenger airliners, it has been found by engineers of the Consolidated Vultee Aircraft Corporation. Use of this gas instead of air saves weight and permits an increased payload.

Air required to fill the tires would weigh 180 pounds, as compared with 26 pounds for helium. Tests have proved that the puncture-proof tubes will hold the lighter helium gas at the required pressure. An ample supply of helium is available, as the government is now producing more than is needed in balloons and dirigibles, and is releasing some for other uses.

Luminous Paint in Operating Room

➤ THE USE OF luminous paint on the walls, ceiling and floor of an operating room would eliminate shadows from the surgeon's hand and instruments, and reduce danger from the sudden failure of lights during an operation, reports Engineer Morozov of the Soviet Scientists Antifascist Committee.

The light rays appear to come through the solid walls and ceiling. An even light with no shadows is created by using a mercury vapor lamp with a black reflector in the room painted with the luminescent paint.

The paint is made by mixing small quantities of zinc or cadmium sulfide with ordinary paint pigments. It will give off light for about an hour and a half after the invisible ultraviolet rays have been switched off. It is also activated by natural daylight as well as artificial light.

These luminous paints have been thoroughly tested at the Union Electromechanical Institute under the direction of Prof. S. O. Maizel. Walls of a room, painted with the compound before the war, still continue to give off light despite the fact that all the windows were blown out of the building by bomb blast in January, 1941, and the paint was subjected to all kinds of weather conditions for almost three years.

Answers to Chem Quiz on Page 39

➤ IF YOU ARE in too much of a state to locate the towns with the elemental names, here they are. The U. S. Postal Guide is our authority.

Antimony, Utah
Calcium, N. Y. and Pa.
Cobalt, Conn.
Krypton, Ky.
Lithium, Mo.
Mercury, Texas
Neon, Ky.
Platinum, Alaska
Vanadium, N. Mexico
Zinc, Ark.

The Sugar Molecule is Built up Step by Step

From Dioses to Disaccharides

by HELEN M. DAVIS

Carbohydrates, fats and proteins are well known as the three classes of foodstuffs. Less well known, perhaps, are the chemical structures of these substances, their inter-relationships and their connections with chemicals met in other places than the dinner table. The various classes of sugars are discussed here, to be followed in later issues by similar reviews of the chemistry of the other food elements.

CARBOHYDRATES, on ultimate analysis, are found to consist of carbon, hydrogen and oxygen in the proportions CH_2O. This suggested to early investigators a compound of carbon and water, hence the name carbohydrate. It represents a naive view of organic chemistry.

The modern chemist determines not only the proportions of the elements in a compound but the patterns in which they are combined as well as, if possible, the absolute number of each kind of atom in the molecule. In the case of the sugars this is fairly simple. The lowest members of the series have the formula $C_6H_{12}O_6$. Nevertheless it has taken more than a century to reach a reasonably accurate understanding of them. Starch and cellulose, also carbohydrates, with the empirical formula $(C_6H_{10}O_5)_n$, have such large and complex molecules that the number of atoms can only be determined as of the order of thousands. It may never be possible to prove by synthesis all the permutations and combinations of C, H and O which will satisfy our ideas of what a carbohydrate really is.

The organic chemist starts with a material whose ultimate analysis he has determined and studies the way the material behaves with various reagents and under different conditions. From this evidence he makes a guess as to how the atoms are combined, then performs experiments calculated to change material combined in that way into something whose constitution he can identify. Working often on a part of the molecule at a time, he can puzzle out the structure of the substance he is investigating. When he has determined the structure to his satisfaction he can start with simple compounds and try to build up the complex molecule. In this way the structures of the various sugars have been determined.

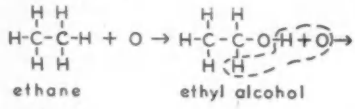
The properties of chemicals depend upon the number and arrangement of the atoms of a small number of elements, in the case of the carbohydrates, three. Similar arrangements give similar properties to the compounds. Having to deal with vast numbers of possible arrangements, the chemist, like the mathematician, likes to deal with series and classes, whenever possible, instead of individual units.

Aliphatic Hydrocarbons

SUGARS are related to the aliphatic series of compounds. They do not contain the well-known benzene ring. Their carbon atoms tend to join, one onto another, to form long chains. It is of interest to explore the lower members of the series to learn at what point the properties of the sugars begin to appear, and as the result of what combinations.

The simplest aliphatic series is made up of compounds of carbon and hydrogen only. The first six members of this series are: CH_4 methane, C_2H_6 ethane, C_3H_8 propane, C_4H_{10} butane, C_5H_{12} pentane, C_6H_{14} hexane. The formula is C_nH_{2n+2}. The sponsors ran out of names at 5 and fell back on Greek number prefixes. Octane, of gasoline fame, is number 8 in this series.

When the carbon and hydrogen compounds of the aliphatic series combine with oxygen, several series of compounds result, depending on the amount of oxygen and the arrangement of the atoms in the molecule. Taking ethane as the type, the oxidation compounds are: C_2H_6 ethane, C_2H_5OH ethyl alcohol, CH_3CHO acetaldehyde, CH_3COOH acetic acid. The diagram (1) will show how these changes occur.



(1)

Each of these reactions can happen to each member of the hydrocarbon series mentioned above, so that we find, for example, CH_3OH methyl alcohol, C_2H_5OH ethyl alcohol, C_3H_7OH propyl alcohol, C_4H_9OH butyl alcohol, $C_5H_{11}OH$ amyl alcohol, $C_6H_{13}OH$ hexyl alcohol. Individual names last a little longer in this series.

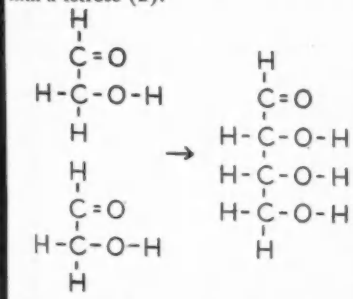
This list by no means exhausts the alcohols formed by one hydroxyl group in this series, for, beginning with C_3H_7OH, it makes a difference in the resulting compound whether the OH is attached to an end carbon atom in the chain, or to the middle one. In this instance $CH_3 \cdot CH_2 \cdot CH_2OH$ is normal propyl alcohol, $CH_3 \cdot CHOH \cdot CH_3$ is iso-propyl, commonly sold as rubbing alcohol. And so forth.

Beginning also with propane, the three-carbon chain, a new type of oxidation product is possible, the ketone, $CH_3 \cdot CO \cdot CH_3$. Because the CO is the characteristic ketone radical, while CH_3 is the methyl group, this compound is sometimes called dimethyl ketone. The chemist is especially interested in these groups. Just what name he gives to the compound resulting from their combinations depends upon his point of view. The same compound may have many aliases, but each is meaningful.

Quite early in the history of sugar analysis it began to be suspected that sugars contain aldehyde and/or ketone groups. Reactions characteristic of these groups were among the keys that unlocked the carbohydrate molecule.

Sugar, however, is not as closely related to ethyl alcohol, a monohydric alcohol (one hydroxyl group), as it is to another series, the polyhydric alcohols. In ethyl alcohol, one hydrogen of one of the CH_3 groups that make up the ethane molecule has been replaced by an OH group: $CH_3 \cdot CH_2OH$. By appropriate reactions, one hydrogen in the other group can similarly be replaced by hydroxyl: $CH_2OH \cdot CH_2OH$. The resulting product, a dihydric alcohol (two hydroxyl groups), is ethylene glycol, widely used in recent years as an antifreeze liquid in automobile radiators. The syllable 'gly-" in its second name betrays the fact that a sweet taste is beginning to appear in this series of compounds.

Oxidation of dihydric alcohols proceeds as was shown above in the case of one hydroxyl group. When one of the OH groups in ethylene glycol is oxidized, glycolic aldehyde: $CH_2OH \cdot CHO$ is formed. This is sometimes called an aldodiose and considered the lowest member of the sugar series because, while it is not itself a sugar, two molecules of it polymerize to form a tetrose (2).



(2)

All the hydrocarbons higher than ethane can form a series of glycols, by replacing two hydrogen atoms with hydroxyl radicals, and the properties will vary according to which carbon atom of the chain has a hydroxyl group attached to it. In following the trail of the sugars, however, we must keep to the polyhydric alcohols in which each carbon atom of the chain holds one hydroxyl.

Corresponding to propane, $CH_3 \cdot CH_2 \cdot CH_3$, we find glycerol, a trihydric alcohol, $CH_2OH \cdot CHOH \cdot CH_2OH$, better known outside the laboratory as glycerine. Being an alcohol, the chemist makes its name end in -ol. Glycerol oxidizes to an aldehyde: $CH_2OH \cdot CHOH \cdot CHO$, known as glyceric aldehyde, an aldotriose; or to a ketone: $CH_2OH \cdot CO \cdot CH_2OH$, known as dioxyacetone, a ketotriose. The -ose endings show that these compounds are considered to be sugars. They are not, however, substances the housewife would recognize by that name.

The next member in this polyhydric alcohol series, corresponding to butane, is the tetrahydric alcohol erythrol: $CH_2OH(CHOH)_2CH_2OH$. It is interesting because it was first synthesized from divinyl, which is butadien, one of the substances from which synthetic rubber is made. Erythrol forms an aldehyde, $CH_2OH \cdot CHOH \cdot CHOH \cdot CHO$, an aldotetrose, and a ketone, $CH_2OH \cdot CHOH \cdot CO \cdot CH_2OH$, a ketotetrose.

Proceeding in the same manner, we come next to the pentose $CH_2OH(CHOH)_3CHO$, arabinose, which gets its name from gum arabic. This brings us to the kind of carbohydrates with which sugar analysis started, and the hexoses, which are true sugars.

Right Hand or Left Hand

➤ At this point it is necessary to notice some of the odd realities resulting from atom structure. One of the first pieces of research which engaged the attention of Pasteur was the relation between the crystalline forms of tartrate crystals and the power that the solutions of those crystals have of turning a beam of polarized light in a right-hand or a left-hand direction. Duclaux in "Pasteur, the History of a Mind" (Smith and Hedges translation), describes the crystal phenomena:

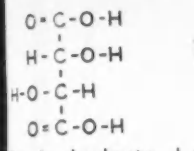
"The crystals of the different tartrates have the most varied aspects; there are needles, tabular crystals, and prisms; they are more or less covered with facets which cut off their angles or their edges and mask their primitive form. But in spite of the variety of their physiognomy there are some features which remain immutable among them and constitute their family mark. These features are three facets which always succeed each other in the same order and make between them very nearly the same angles. . . .

"Let us agree to place this right line vertically in our tartrate crystals and to turn forward the group of three facets which is that characteristic the different crystals have in common. All the crystals can thus be ranged, in spite of the variety of their forms, in an oriented series like soldiers exhibiting in front the same series of buttons. But when one has arranged them thus he perceives with surprise that all of these soldiers bear only one epaulet, turned in every case in the same direction: I mean to say that all these tartrates have their hemihedral facet inclined forward to the right of the observer.

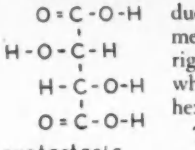
"If one turns them half-way around they are like children's lead soldiers, or like the god Janus, inasmuch as the front cannot be distinguished from the back: the hemihedral facet from the rear is now in front, but it is always to the right. If one reverses them in order to observe them from the other end they resemble then the double figures on playing cards; their extremities resemble each other and however one places them, provided that one puts in front the characteristic group of the three faces that we have pointed out, one of their four hemihedral facets comes again obstinately to take up its position facing the observer, and at his right."

Pasteur was able to show that the right-handed-ness of the crystals accompanies dextro-rotary power of the solution for polarized light, that there are also left-handed crystals whose solutions turn the plane of polarized light to the left, and that there are two optically inactive forms, one consisting of a mixture of equal quantities of right- and left-handed crystals, the other, in Duclaux' language, "wearing epaulettes on both shoulders."

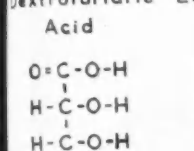
Crystal form and optical property have been found to depend directly upon the pattern of the atom groups in the molecule. The linkages shown in the chemist's structural formulas are no mere figures of speech. The molecular structures giving rise to these differences in properties are shown in (3):



Dextrotartaric Acid



Levotartaric Acid

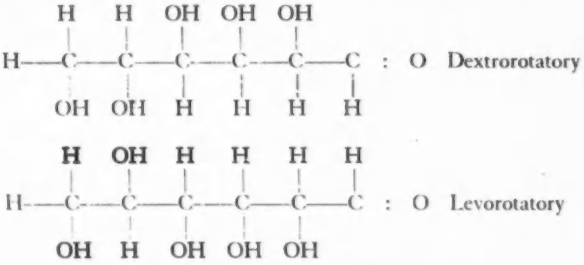


Mesotartaric Acid

A mixture of Dextrotartaric and Levotartaric Acids is known as Racemic Acid (3)

As the carbon chain increases in length, there is more and more opportunity for differences in structure due to this phenomenon of stereoisomerism. Below are the formulas of a right-handed and a left-handed aldose, which are only two of the possible 16 hexoses of the same composition.

The convention by which the exact pattern of the molecule is assigned to the specific sugar is, in this case, that, starting with the CH_2OH group, which is common to all these sugars, the first hydroxyl radical following this group is on the left in the levorotatory form and on the right in the dextrorotatory. Once this convention was established, the relationships of all the sugars to each other could be matched to differences in molecule pattern, and all crystal form, polarimeter and X-ray diffraction pattern data seem to be in agreement with the patterns so chosen.



Disaccharides

Although the structure of the hexoses may seem complex beside that of the simple hydrocarbons, these sugars are themselves simple units in the structure of the carbohydrates used so commonly in daily life. Cane sugar, milk sugar and malt sugar, for which the term saccharobioses has been coined to emphasize their production by living organisms, have the formula $C_{12}H_{22}O_{11}$. It has long been known that hydrolysis by acids or ferments will split these double sugars into hexoses.

Diastase, an enzyme produced by sprouting grain, will change one molecule of maltose into two of dextrose, a right-handed aldose of the type whose molecular pattern was illustrated in the previous section. This is the reaction upon which the manufacture of beer is based, and has been known

at least since the time of the ancient Egyptians.

Milk sugar, which has been consumed by the human race for a very long time but only studied recently, is similarly split, but the two aldoses which result are different. One is the same dextrose as results from maltose. It is sometimes known as grape sugar. The other is another right-handed hexose of the same composition but different pattern, known as galactose.

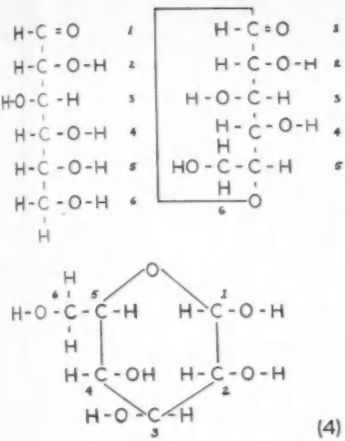
Cane sugar, best known of the saccharobioses, splits into a right-handed and a left handed hexose, dextrose or grape sugar and levulose or fruit sugar. The splitting process is often called inversion and the products invert sugars. Levulose differs from the other invert sugars, not only in its action on polarized light but also in its structure. It is not another aldose, but a ketose.

In spite of all the study that has been made of sugars during the past century, the significance of one of the obvious phenomena displayed by sugar solutions has been understood only recently. The phenomenon is the change in the amount of rotation of polarized light that the invert sugars show after standing a certain length of time. The change in rotation was observed almost from the beginning of the use of polarimeters in sugar identification, but the reason was ascribed to equilibrium or to oxidation. Some sugars show increased rotation, others lessened. The differences are large. Sometimes one reading is twice the other. The phenomenon is called bi-rotation or muta-rotation. The explanation goes back to the pattern of the molecule.

These invert sugars have been known for a long time, and have received a good deal of study from various points of view, especially because they are the sources of alcoholic fermentation. Cane sugar does not support ferments until it has been hydrolyzed into its monosaccharides. The chemistry of fermentation has been thoroughly studied and the steps by which dextrose and levulose are broken down into ethyl alcohol and carbon dioxide have been worked out with fair certainty. It would take too much space to present them here. Although the chemist in his more theoretical moments is apt to think of the employment of living reagents like yeasts as " not quite cricket," he does not hesitate to use these ancient processes for practical results, and his understanding of their possibilities is constantly increasing.

Rings

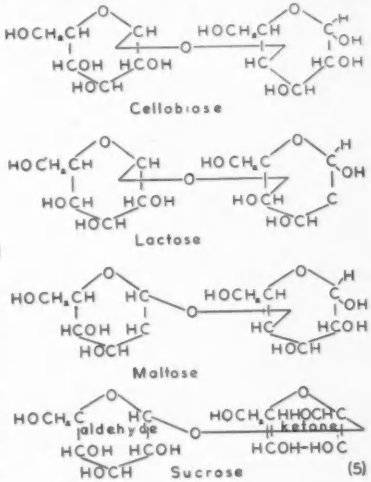
There is no doubt that the hydrocarbons of the aliphatic series form long chains, adding new carbons in a straight-line relationship to those already in the molecule. There is also no doubt that the corresponding trioses, tetroses and pentoses also have straight-line formations. The hexoses are different. They have a marked tendency to turn and catch their tails in their mouths, so to speak, with the formation of a ring structure. Although there are six carbon atoms in these sugars, they do not form a six-member carbon ring, like benzene, but a ring formed of five carbon atoms and one oxygen atom, with the sixth carbon atom in a side group. The re-arrangements necessary to form the ring are shown in diagram (4):



(4)

It is to the effects brought about by this ring structure that the phenomenon of muta-rotation is due. 99% of the sugar in any invert sugar solution is believed to have the ring formation, only one per cent the straight chain. Now, in addition to the right-hand and left-hand effect, which the sugar chemist expresses by D and L, we find also the arrangement of radicals with reference to the plane of the ring. One convention for writing the formulas is that the oxygen atom is always written at the top of the ring, the carbon atoms are numbered around from it in a clock-wise direction. Carbon atom number six is written outside the ring (which is interpreted as meaning above the plane) in the D series of sugars, and inside the ring (below the plane) in the L series. It is no wonder the sugar chemist uses letters, numbers, plusses and minuses, and the Greek alphabet to keep all his compounds straight.

When we come, now, to combining these monosaccharides to form disaccharides, still another space relationship is introduced. The linkages in the structures of the three sugars already discussed and a fourth cellobiose, very much like milk sugar,



(5)

which results from work on starches and cellulose, are shown in diagram (5):

The two invert-sugar rings are joined by an oxygen atom in the so-called *oside* linkage, which causes differences in the bioses due to tipping the planes of the rings in relation to each other. At this point the sugar chemist usually borrows his child's construction blocks and goes in for space models.

Chemistry of the starches and the celluloses will continue the story of the carbohydrates in the next issue of CHEMISTRY.

Tests You Can Do In the Kitchen
Simple Enough for Children to Try

Home Experiments With Sugars

▶ IT IS FUN to find out what sugars there are and how they differ from each other. Here is a standard test which can easily be done in your home with very little equipment beside what you already have. It is convenient to have a few test tubes, which your druggist either has in stock or can easily get for you. They are only a few cents apiece. The value of the test tube is that you can heat liquids to boiling in it and see what happens. (Don't try to heat a drinking glass over a flame; it will break.)

To hold your test tube, you need some tongs. Your kitchen may be already equipped with a pair. A prewar spring-jawed clothes pin makes a good substitute. Avoid accidents by being prepared, as in cooking. Gas flames and boiling water will burn you if you get too near them. Glass will break if handled carelessly, and the pieces are sharp. Plan what you are going to do with hot test tubes before you heat them, avoid spilling, have a good first aid kit (filled) at hand, and work carefully.

Sucrose or Hexose?

The test which will point out to you which sweets are sucrose and which are invert sugars is made with a test solution you can buy cheaply at your neighborhood drug store. Ask for Benedict Solution, qualitative grade. You will get a clear liquid of a beautiful blue color, due to copper sulfate in the solution. This is the standard reagent used for check-up on diabetic patients. Twenty-five cents will buy plenty for the tests you want to make. Heating with an invert sugar will make the copper come down almost at once as an orange or red precipitate (cuprous oxide). Cane sugar (the kind you usually buy with your ration stamp) will leave the solution clear when first heated. After boiling for more than five minutes, the cane sugar will gradually change to invert sugar, and then the precipitate will begin to appear.

How many sugars can you find in your kitchen? There are white sugar and brown sugar, molasses, various kinds of table syrups, maple sugar, maple syrup, and honey. If you buy some milk sugar (lactose) from your druggist you will make the acquaint-

▸HEATED *in a pan of boiling water, white sugar and maple syrup are tested with the Benedict solution.*

➤ ONE KIND *of sugar shows a precipitate, the other solution remains clear. How many sugars do you know?*

ance of a very interesting and different kind of sugar.

Then you can test different kinds of candy, prepared puddings and gelatins, and malted milk powder. Make an accurate record of your results as they happen. (Have paper and pencil ready before you start and have a place to write.) Mark your tests so you can't mistake which is which. A small paper label may be pasted near the top of the test tube, and the name of the material written on it, or a wax pencil will mark directly on the glass. Take time to rub out the name after each test and record the new material. Don't use codes or numbers; ten to one you'll get them mixed up.

Use a small amount of material for your tests. A very few crystals of your precious sugar are enough. Dissolve them in enough water to come only an inch or less up the test tube. Pour in about half as much Benedict Solution as there is water in the test tube. Set the tubes in a pan of water and boil for five minutes. Time the heating period. Invert sugars will precipitate quickly. Sucrose may remain clear longer, and then suddenly begin to precipitate. Along with the test, you may want to "run a blank." If you use water instead of sugar solution with the Benedict reagent in one test tube, you will see that continued boiling alone does not bring down the red precipitate.

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